Nina
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The Psychology of Learning

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Theories of Learning and Programmed Instruction

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Translated from the Russian
Designed by *Vladimir Solovyov*

Нина Талызина
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PREFACE

The present study is about a further development of the control of learning processes presented in *Theoretical Problems of Programmed Instruction.*[1] This was concerned with an analysis of the principles of a general theory of control that must be taken into account in designing programmed instruction procedures. The present study emphasizes the analysis of psychological theories of learning that are intended to clarify the specific principles that govern the process of human learning. Particular attention is given to the evaluation of the ability of such a theory to make it possible to relate cybernetics to the control of learning processes.

Three conceptions are examined: the stage-by-stage development of mental actions, behaviourism, and the associationist-conditioned reflexes theory. In addition, certain findings derived from experimental studies are presented that are based on P. Ya. Galperin's theory of a stage-by-stage development of mental actions which provides, in our view, the most adequate psychological foundation for guiding the learning process. In particular, possibilities for guiding the assimilation of scientific concepts are shown as well as similar possibilities for consolidating knowledge-acquisition procedures.

This selection of theories is prompted by the actual state of affairs: at the present time they represent the principal approaches to learning in psychological science, which have been reflected in the area of programmed instruction.

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[1] N. F. Talyzina, *Teoreticheskiye problemy programmirovannogo obucheniya* (Theoretical Problems of Programmed Instruction), Moscow State University Press, 1969.

The cybernetic conceptions that are needed of analyze psychological theories of learning and to understand the approach to the programming of the knowledge-assimilation process that is proposed are presented in the first chapter, which links the present study to our preceding work.

We are aware of the incomplete nature of the conception of programmed instruction that we are proposing, and of the debatable character of certain propositions. Nevertheless, we hope that this work will play a constructive role in drawing attention to a psychological theory of learning as one of the major theoretical elements of programmed instruction.

This study is addressed both to specialists in the theory of instruction and to practitioners who are interested in problems of programmed instruction and are seeking to introduce the achievements of psychology and pedagogics into the teaching-learning process. It may also serve as a text for post-graduate students in studying the foundations of the teaching-learning process in post-secondary schools, as well as for students of psychology following courses in educational psychology.

It is with pleasure that I express my gratitude to my teacher, Professor P. Ya. Galperin, on whose ideas the present study is based, as well as to Professor N. F. Dobrynin, Professor F. F. Korolyov, Professor A. N. Leontiev, Professor D. B. Elkonin and other associates who have read this study at various stages and have contributed important comments and valuable suggestions.

I also wish to express my gratitude to colleagues who have contributed directly to the research activities that are described in this study, to discussions, and to the preparation of the manuscript for publication.

INTRODUCTION

Scientific and technological progress has produced a number of trends that may be found in all fields of social practice. They include the application of science to practical activities, changes in the proportions of the various functions performed by man (an increasing liberation from operational activities and a growing role in managerial activities) and an increasing measure of automation as a growing number of new types of human activities are assigned to machines.

These trends may also be observed in the sphere of education. In particular, they underlie the conception of programmed instruction. Indeed, the essence of the idea of programmed instruction proposed by B. F. Skinner is a call to increase the effectiveness of the activities that control the process of learning by making use of the findings of experimental psychology and of teaching machines (298; 301).[1] To optimize the process that controls man's learning activities is both the objective and the content of programmed instruction, while modern psychology and modern equipment constitute the required means.

The functions of teachers have always included not merely the communication of knowledge, but the control of its assimilation as well. The achievements of science and the technological revolution have created possibilities for raising such control activities to a level that is qualitatively new. But these factors have also confronted the practical activities associated with teaching with a need to increase the volume of knowledge and improve its quality, and to prepare students for a continuous education. This is not possible, however, without increasing the effectiveness of both the knowledge-acquisition control process and teaching-learning activities generally.

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[1] **References cited can be found under the indicated number in the list at the end of the book.—*Ed.***

Thus the very course of society's historical development has not only led to the emergence of the idea of programmed instruction but has made possible its wide dissemination.

In selecting the most productive approach for developing that conception it is important both to analyze the relative importance of the several tendencies that it embodies and identify possibilities for its future development.

The trends that are reflected in the idea of programmed instruction are objectively linked with each other and this must be taken into consideration in developing and introducing programmed instruction. An optimal approach to the control of learning requires a comprehensive reliance on relevant scientific knowledge. In raising the level of control of human learning it is not sufficient to rely on the achievements of experimental psychology alone. It is equally important to rely on knowledge from other sciences and above all from cybernetics, which is the science of control processes. But cybernetics specifies only the general requirements that bear on effective control. These cannot be applied without considering the distinguishing features of particular control processes. The further development of problems of programmed instruction must therefore also rely on the psychological and pedagogical sciences concerned with the specific properties of particular teaching-learning processes.

The development and implementation of programmed instruction will therefore be effective only if use is made of both a general theory of control and a psychological and pedagogical theory of learning. In this connection it is important to recognize that in applying the relevant requirements of cybernetics it is not only necessary to take into account the specific features that attach to the process of human learning but to do this in a manner that reflects the nature of that process. It is also possible that the specific features attaching to the control of human learning are such that they require a partial revision and further elaboration of the concepts of cybernetics.

At the same time a comparison of cybernetic requirements with the current state of psychological and pedagogical knowledge on the learning process serves to identify still unsolved psychological and pedagogical problems whose clarification is needed in order to develop an effective control of the learning process.

With regard to the automation of the teaching-learning process that is implied by programmed instruction in the context of mass teaching activities it should be emphasized that technical specifications relating to equipment follow from the characteristics of teaching programmes. But teaching programmes embodying scientific principles are themselves designed in the light of a general theory of control and a general theory of learning. Ultimately, it is these fields that therefore define the specifications of appropriate automated devices.

The idea of programmed instruction is thus concerned with increasing the effectiveness of processes that guide learning by relying on modern knowledge of control processes and on knowledge of the specific characteristics of the learning process as well as on the support of modern technology. These aspects of programmed instruction may of course be considered more or less separately. But it is also necessary to recognize that they are interrelated and that a major role is played by modern scientific views of the principles that govern the learning process. Yet, an analysis of the ways along which programmed instruction continues to develop today shows, first, that its problems are usually being met without the help of an adequate scientific basis; second, that the technical equipment employed in programmed instruction is developed without considering the nature of the learning process; and finally, that in developing individual aspects of the idea of programmed instruction its principal underlying idea, namely, optimizing the control of learning, is neglected. This produces new approaches whose scope exceeds that of programmed instruction.

The first of these facts, namely, an underestimation of an adequate scientific theory, is found in at least three approaches to the development of programmed instruction: a one-sided psychological approach, a one-sided cybernetic approach, and an empirical approach.

The one-sided psychological approach derives from B. F. Skinner, who is the founder of programmed instruction. With regard to the control of the learning process his supporters rely exclusively on psychological theories, among which behaviourism is especially widespread in other countries at the present time. It was Skinner who first used it as a scientific basis for the control of the learning process.

Attempts are also being made to rely on the theory of Gestalt psychology. Until now, however, they have not produced any noteworthy results.

In our own country an increasing number of researchers have been turning to the theory of stage-by-stage development of mental actions proposed by Galperin in the early 1950s that has since continued to be developed by his former students and disciples both at the theoretical level and experimentally. In addition proposals have been made to rely on an associationist-conditioned reflexes theory in designing instructional programmes. Its elements have been formulated by D. N. Bogoyavlensky, N. A. Menchinskaya and Yu. N. Samarin.

The shortcomings of that approach derive from its neglect of the achievements of cybernetics, which is the science on the general principles of control, in an effort to optimize the control of the learning process.

At the other extreme *advocates of a one-sided cybernetic approach* in guiding the process of learning tend to rely on cybernetics alone. Such an approach has become known as the cybernetic theory of education. Actually the corresponding studies include both studies in cybernetic education and in pedagogic cybernetics.

The confusion of these two distinct sciences is harmful to the development of both. Cybernetic studies of the teaching-learning process are concerned with an analysis of instruction as a cybernetic system. Such studies are inevitably associated with a formalization of pedagogical phenomena and with abstraction from their specific contents. The process of instruction is a complex and specific form of control that may offer cybernetics itself new principles of behaviour. Because they are abstracted from the process of instruction, they may lead to the formulation of additional conditions that are important in regulating particular types of processes. That such studies are justified and important from the point of view of cybernetics is evident. But when they are carried out under the name of research in cybernetic pedagogics, i.e., as studies in education, this produces a justified protest among many representatives of pedagogical science. In particular, they see in a formalization of the reality of the pedagogical process the danger that their science will lose its ideological content and its specific characteristics. Frequently, however, that protest is directed against any reliance of the theory of education on cybernetics. It is therefore important not to confuse these distinct scientific approaches.

Another consequence of such one-sided overemphasis on a cybernetic approach and of a neglect of psychological theories of learning frequently is a tendency to apply to the educational process characteristics of other less complex processes. In particular, principles that are relevant to the regulation of technological systems may be applied to the control of learning processes.

Empirical approaches to developing and introducing programmed instruction are especially widespread. These neglect both cybernetic and psychological theories. Both the development of programmed instruction procedures and resolvement of problems associated with their implementation then merely rely on general pedagogical experience and common sense. At best only individual elements of cybernetics and of psychological science are then employed.

The unproductive character of empirical approaches has now been shown by experience: more than 15 years of work have not produced any significant advances in relation to any major problem of programmed instruction.

The second characteristic in the development of the ideas of programmed instruction that we have mentioned, namely, isolated studies of technological equipment that may be employed in instruction, has produced numerous teaching devices that do not conform to the nature of the knowledge-assimilation process. This has led to situations in which it is not the requirements of the learning process that define the technical specifications of equipment, but rather the reverse, that is in which the learning is adapted to the technical capacities of machines.

While an automation of the functions of a teacher may reduce the need for his services it is by no means always true that it will enhance the quality of the resulting control of the knowledge-assimilation process. Technical designs of teaching devices that ignore both the psychological and pedagogical foundations of the teaching-learning process and the objective of programmed instruction, namely, the enhancement of the control effectiveness of learning processes, have rapidly produced a situation in which such an approach has begun to experience an autonomous development without regard for programmed instruction itself. This has placed a major emphasis on the development of control devices concerned with automating the administration of various types of examination. More recently there has been an intensive development of educational films and television. They are intended to either replace or else supplement teachers as the source of new knowledge.

Like many other types of equipment for automating the teaching-learning process, these devices do not improve the form of control that is employed. Since the emergence of the idea of programmed instruction allowed an intensive development and application of technical means in education, all forms of automation of teaching generally continue to be associated with programmed instruction and are frequently identified with it.

It should be recognized that in fact such a confusion of programmed instruction with automation is harmful as well as misleading. In particular, it has inhibited the further development of that important idea, whose emergence is entirely natural. The automation of individual functions of the teaching process has not in fact produced an improvement in the quality in the process of knowledge assimilation. Moreover, the use of technical means that do not meet the specifications of the teaching-learning process have led to a deterioration in its quality, and this has naturally caused disenchantment among practitioners. But such a disenchantment with the effectiveness of the equipment has also created an unjustified disenchantment with programmed instruction itself and today many specialists in the field of education as well as many practizing teachers hold the view that programmed instruction has not justified the hopes that it had aroused and that its time has passed. Unfortunately that view is also shared by the editorial boards of a number of journals in the field of education.

Still another branch of knowledge that has originated in programmed instruction concerns the scientific organization of labour activities in the field of education. Even more than does programmed instruction itself that branch reflects a trend towards applying science to practical activities. For programmed instruction is only concerned with providing scientifically grounded forms of control with regard to the learning process, without concerning itself with such problems as the nature of learning objectives under conditions of progress in science and technology, the principles that bear on the design of courses, the time budgets and assignment norms of various learning activities that call for a more general reliance on scientific knowledge. In such a context programmed instruction, which is concerned with a development of scientifically grounded principles of control of the learning process is only part of the wider problem of scientifically based teaching-learning process.

Finally, the idea of programmed instruction has produced a branch of knowledge whose objective is to optimize the control of the overall education and training process and first, an optimization of its administration.

Even though both groups of researchers are concerned with the control of the teaching-learning processes, different control systems concerned with distinct control objects are in fact being considered. In the case of programmed instruction the object of regulation is the process of learning itself. In the case of the control of administrative processes, on the other hand, it is a group of students—either in particular courses or in a wider sense. In both cases the organization of effective control must meet a system of common requirements inferred from the general theory of control but its implementation is subject to the different specific principles in each case that govern the control of the corresponding process (object).

Thus, trends originating in scientific and technological progress have reached the sphere of education through the idea of programmed instruction. Very soon, however, they began to follow an autonomous course of development, lost their initial reference to problems of programmed instruction, and became autonomous branches of knowledge.

While programmed instruction calls for research activities in all of these branches, these must relate to the control of the learning process itself.

In short, a successful development and introduction of programmed instruction may require that the following conditions be met: first, that these specific principles governing the teaching-learning process that have been established in psychology and education theory be taken into account;

second, that the requirements and specifications of the general control theory be followed; and third, that automatic devices be employed, since knowledge assimilation cannot be controlled without their appliance under conditions of mass teaching activities. The further development of the idea of programmed instruction must thus include: a) the selection of a psychological theory of learning that meets most closely the characteristics that are specific to the human learning process; b) the identification and realization of requirements of the learning process control that are inferred from a general theory of control; c) the design of a set of technical teaching devices that embody them.

Chapter One

GENERAL PSYCHOLOGICAL AND CYBERNETIC ASPECTS OF INSTRUCTION

As a branch of psychological science the theory of learning must reflect the methodological principles of psychology that follow from the Marxist understanding of the psyche and from Marxist teachings on human consciousness. Soviet psychologists have recorded many successes in their long struggle for the use of Marxist methodology in their science. At present the principal task is to apply these principles in a consistent manner to all specific theories associated with individual branches of psychological science and to develop these principles to the stage at which they may be applied to concrete experimental activities.

A second major task is to analyze in the light of these principles the knowledge that has been accumulated in this branch of psychology. But an equally important task concerns the rejection of unacceptable methodologies. Objectively, the idea of programmed instruction has posed such a threat: aside from formulating the idea of programmed instruction, B. F. Skinner has also developed a version of programmed instruction that is based on a behaviourist conception of human learning itself. Unfortunately, many advocates of programmed instruction fail to distinguish between that general proposal and the specific approach that has been proposed for its implementation. A study of the practice of programmed instruction in our own country shows that it is not yet free of the influence of its American behaviourist version. In such a situation it is particularly important to recall the major stages in the development of the principles of Soviet psychology and also their specific contents.

§ 1. The Emergence and Consolidation of the Principles of Soviet Psychology

Following the October Revolution the task of a conscious and planned development of psychological science on the basis of Marxist philosophy was posed for the first time in history. On the one hand it was necessary to overcome subjectivism and phenomenalism in psychology as well as the separation of the psyche from the actual activities of persons operating as carriers of social relations. At the same time it was necessary to overcome a simplified mechanistic approach that was destructive for the specific properties of psychic phenomena and for scientific approaches to psychology.

The first major step was taken by L. S. Vygotsky. Already in his early studies he was able to show that the principal flaw in subjective idealistic psychology and reflexology concerns the separation of the psyche from behaviour (21). A separation of the psyche from behaviour inevitably leads to a mechanistic approach to the analysis of behaviour and to a subjective idealism in understanding the psyche. In this connection Vygotsky observed that "just as there can be no behaviour without psyche, there is no psyche without behaviour" (22, p. 41).

The principle that there exists an integral unity of psyche and activity, which was subsequently elaborated by a number of Soviet psychologists and which is the major principle of Soviet psychology today was thus introduced through these works of Vygotsky.

More specifically, Vygotsky noted that in order to understand psyche and consciousness it is necessary to move beyond their immediate sphere and consider the life of the individuals concerned under specific conditions of existence. In his view the development of human consciousness is based on the development of the person's practical relations to reality. But he did not assert that there exists a direct relation between the consciousness and practice of individuals. For he believed that the major element in the development of the human psyche is the assimilation of social experience. The formulation of a social and historical approach to human psychology was thus also contributed by Vygotsky (86). The cultural-historical theory that he subsequently developed (24; 25) in which he sought to analyze the specific properties of man's psyche as an outcome of his societal life was a concrete embodiment of these propositions.

Man's labour activities are characterized by the use of instruments that mediate his relations to his conditions of existence. It is precisely this element of mediation that distinguishes man's interaction with the world from that of animals.

That element of mediation, as a specific characteristic of the practical activities of human beings, has produced corresponding changes in their psyche: it, too, came to be mediated. It is signs (labels) that operate as mediating elements in man's psychic processes. While externally directed means of labour produce changes in objects within his external environment internally directed signs play the role of instruments that produce changes in psychic processes.

Initially signs are embodied in an external and material form, but subsequently they are internalized and become ideal. The basic system of signs mediating man's psychic activities is provided by language. It, too, derives through a process of internalization: at first language is employed in communicating with other persons, but it is then employed individually at the level of internal speech.

Speech originated as a specifically social form of relations among persons and was brought into existence by their social practice. The specific characteristics that attach to man's psyche thus derive not directly from human practice but from the social relations among persons (speech) that develop on such a basis and form products of their culture (language). Hence the cultural-historical nature of human psyche (89).

The role of such instruments—of signs—relates to their ability to alter the structure of the psychic processes that they mediate. In the opinion of Vygotsky this is their most important characteristic. Vygotsky shows that the development of mediated psychic structures leads to the appearance of new linkages among individual psychic functions and that this in turn leads to a restructuring of the functions themselves. Thus in order to understand the specific characteristics of individual psychic processes it is necessary to turn to an analysis of the structure of the overall system that they form. Consciousness, as Vygotsky points out, possesses a systemic structure. In other words the element of mediation leads to the formation of new interfunctional relations rather than to changes in individual psychic functions.

A systems-oriented approach to the analysis of the psyche opens the way to an overcoming of functionalism and this, too, is an important task of Soviet psychology. Consciousness appears not as a sum of individual invariable psychic processes but as a dynamic system.

The use of instruments—in the present case of signs—permits man to control his behaviour and to control his psychic processes which are thus transformed from lower, natural, unmediated and reflexive forms into higher, social, mediated and willed forms. Thus, mediating instruments initially appear as external material elements that are employed in relation to joint, collective activities in order to organize the behaviour of other persons. Gradually, they become internal and psychic, and are used individually in order to control one's own behaviour and one's own psyche.

In the cultural-historical theory the close association of the psyche with external practical activities follows several lines of development. First, specific features of the practical activities of human beings emerge as determining elements in relation to the specific characteristics of their psyche. Second, the structure of the human psyche is viewed by analogy with the structure of his labour activities. Finally, mediated psychic functions emerge, first in the process of external joint activities. Speech and other instruments (signs) originally serve as their corresponding elements. "All higher psychic functions in a child's development appear on the scene twice: initially as a collective and social activity, i.e., as an interpsychic function, and the second time as an individual activity, as an internal method of thinking by the child, as an intra-psychic function" (26, p. 449).

In seeking to acquire control over his behaviour and to regulate his psyche man initially sought the support of external objects. It is only later that he acquired the capacity to do this internally on the basis of an external mediation, seeking support in internal ideas that have become elements of psychic activity.

Vygotsky considers psychic phenomena as the outcome of transformations of external, material phenomena only in relation to mediating links, i.e., to "instruments". The corresponding psychic processes which that "instrument" mediates, are not shown as transformations of external phenomena. At the theoretical level the recognition of a genetic relation between internal psychic forms of activity and external activities (as the basis for the former) is extended in Vygotsky's work to the entire psyche. "Any higher psychic function unavoidably passes through an external stage in its development" (28, p. 197). But it is important to emphasize that in examining problems of internalization he did not merely stress the transferring of external behaviour internally (this had already frequently been noted earlier). For him the major point concerned the transferring to the internal world of social experience. "For us to say that a process is 'external' is equivalent to saying that it is 'social'" (*Ibid.*). In short, the process of internalization makes it possible to show the social nature of man's psyche in concrete ways. Paraphrasing Marx's well-known proposition, Vygotsky wrote: "Man's psychological nature represents an aggregate of social relations that have been transferred internally and that have become functions of personality and forms of structure" (*Ibid.*, pp. 198-99).

Having established the foundations underlying the principle of the integral unity of external activities and of the psyche as well as of an approach to man's psyche as a phenomenon that is social by its very nature, Vygotsky was not able to follow them consistently in his concrete psychological studies and became a victim of the very intellectualism that he opposed. In attributing a decisive role to instruments, Vygotsky has stated that these can carry out their functions only because they are always reflections of something and possess a specific *meaning* for man. This is true, he stated, of the utilization of both internal and external instruments. It then follows that the process leading to the development of mediated psychic forms is in fact the process of development of meanings. In their most characteristic form meanings are represented by words. It follows that one should trace the manner in which words acquire their meaning. But since Vygotsky did not see any difference between meanings and concepts, it was the process of the development of concepts that was subjected to experimental studies. Vygotsky sought in the development of concepts the major line of development of consciousness.

In his view it is the level of development of concepts in man that also determines the specific characteristics of the manner in which he reflects the world and possibilities for actively influencing it. As for the development of concepts this is conditioned by a child's joint activities with adults who introduce him to "zones of potential development" (23).

It is in this way that a real danger appeared in Vygotsky's system that emphasis will be placed on communications as a factor determining the development of consciousness together with a neglect of man's practical relations with reality. For the child became not a subject interacting with the real world but merely a creature engaged in social communication. Such an interpretation of the role of social communication carried the danger of intellectualism and idealism (36).

The study of the role of mediating instruments in the development of man's psyche thus expressed Vygotsky's striving to carry consciousness beyond the boundary of a closed circle within the individual and to explain its essence in terms of external forces. But once it was separated from real activities and viewed autonomously the concept of a mediating instrument came to be overemphasized, and this led to a neglect of activities, to intellectualism, and to a closure of relations within consciousness itself. Meanings, which were viewed by Vygotsky as a unit of individual consciousness, came to play a determining role in the structure of the human psyche and in the level of its development.

Yet, this resulted from an insufficiently consistent application of Vygotsky's basic propositions to his cultural-historical theory of the psyche rather than from the nature of these propositions themselves.

There is no question concerning the validity of Vygotsky's basic proposition relating to the determining role of man's practical relationships to reality in psychic development. But instead of bringing out the role of labour activities as a specific type of activity linking man with the world in the development of the human psyche, Vygotsky studied only the role of instruments of labour. Yet, no matter how important they may be, instruments by themselves do not encompass the entire scope of labour activities. In particular, Vygotsky did not analyze the influence on the human psyche of new interpersonal relationships that develop in the course of their labour activities. Beyond this, while noting the socio-historical nature of the human psyche, he sharply opposed natural psychic processes to social ones. In short, in considering the development of the human psyche he viewed social processes and natural processes as two distinct spheres of psychological processes (89, p. 25).

The subsequent criticism of the theory of the cultural-historical development of the psyche did not represent an abandonment by Soviet psychology of the problems to which that theory addressed itself and of the fundamental ways of resolving them proposed by Vygotsky.

In particular, S. L. Rubinstein and A. N. Leontiev and his associates streamlined Vygotsky's theory, gave a more detailed analysis of the relations that link the psyche to practical activities and further developed the principle of the social conditioning of the human psyche.

Following the works of Marx, Rubinstein proposed to view human activity as the subject of psychology (138). Subsequently, this formulation was made more precise: psychology should study not activity itself but its psychological characteristics (139).

Still later, Rubinstein sought to make the definition even more precise. Yet that step towards "greater precision" in fact represented an abandonment of the view that human activities are the subject of psychology: "...a psychology that understands what it is doing, studies the psyche and only the psyche" (140). But this did not mark the end of studies of the role of human activities in the development and functioning of the psyche. On the contrary, Rubinstein stated the principle that the psyche and activity constitute an integral unity: "...as they are embodied in various types of concrete activities, psychic processes are shaped by these activities" (141). Yet specific relationships between activities and the psyche were not identified either on a theoretical level or at the level of experimental psychology. The problem of overcoming the ancient dualism between external practical activities and the psyche as an internal and ideal phenomenon was thus unresolved. In this connection, Vygotsky wrote (21): "Among subjective psychologists we find a psyche without behaviour, while among reflexologists we find behaviour without psyche. But in both cases psyche and behaviour are not *one* but two [distinct phenomena]." The mere statement that the psyche and activities form an integral unity does not automatically cause the *two* things to disappear. That requires that the substance underlying their unity be identified.

In our opinion that problem was solved by Leontiev. Following a critical analysis of Vygotsky's cultural-historical theory his principal objection was the following: it is not concepts (and therefore not meaning, signs or instruments) but real activities linking organisms with their environment that determine development both of overall consciousness and of individual psychic functions (83).

Essentially, Leontiev approaches the psyche not as a phenomenon that accompanies the life of an organism, but as a process that realizes life. It is viewed not as some subjective addition to the organism's life activities but as a form of that activity.

Leontiev has shown that it is the logic of their own development that brought the real relations between an organism and its environment to the need for the emergence of the psyche. For the first time the search for a criterion for the psyche is guided by an analysis of the objective relations that link organisms with their environment. Leontiev proposes that an organism's stimulativeness in relation to certain types of environmental influences serves as an objective criterion for the particular form of life activity called the psyche. More specifically this refers to those types of perturbances from the environment that do not themselves possess a direct meaning for life activities, but, because of their relation to other influences that do possess such a direct significance, play the role of signals and mediate the relation of organisms to directly significant stimuli. Leontiev supposes that such a complexification in the relations of organisms to their environment was produced by a transition from life in a homogeneous and unstructured environment to life in discrete environments, within which organisms found it necessary to effect a search for stimuli possessing a direct vital significance, to orient themselves within such environments, and to reflect them.

Following an analysis of experimental data in the field of animal psychology produced both by other researchers and by himself, Leontiev came to the conclusion that the type of mechanism that effects an adaptation of animals to environmental changes cannot serve as the only criterion for the development of their psyche. He opposes the traditional scheme representing the development of animals.

namely, instinct-habit-intellect. Leontiev has shown that in identifying the major stages in the development of the psyche of animals consideration must be given to the objective structure of those activities of animals that link them to their environment and determine the forms in which they reflect reality. It is on the basis of such an approach (according to forms of reflection) that he identifies the following distinct stages: psyches relating to elementary sensors, perception-oriented psyches, and psyches based on intellect.

Leontiev has also shown the manner in which changes in conditions of existence lead to changes in the structure of the animals' activities (behaviour), while that in turn leads to changes in forms of psychic reflection. In this connection he points out that one never finds a direct correspondence between forms of reflection and changes in the structure of activities: forms of reflection lag behind such changes as it were. In describing different types of activity structures and different forms of reflection, Leontiev also emphasizes that they continue to be constrained by the framework of instinctive-biological laws.

In analyzing the conditions under which human consciousness has emerged, Leontiev shows that there, too, it is the specific characteristics of the activity structures, which now refer to labour and are governed by social relations rather than by natural laws, that produce the specific features of the human psyche.

It is thus *activities* linking the subject to the world that were made the subject-matter of psychology by Leontiev (*Ibid.*). Above all he turned his attention to the structural properties of activities. He objectivized goals and motives as basic elements of activities that are guided by the mind and interpreted them not as internal experiences but as external objects guiding the subject's activities. Thus he views the motives of activities not merely as a need for something on the part of the subject, but as an *embodied need,* as the particular *object* that motivates the subject to undertake activities.

Leontiev distinguishes between the concepts of activity, action and operation. By activity he understands the processes that carry out a living active relation on the part of the subject with respect to reality. Its characteristic feature is a coincidence of motive and objective: it is motivated by the particular objective to the achievement of which it is directed (86). "The basic components of individual human activities are the actions that realize them. We call an action a process that is subordinated to the representation of the particular result that is intended to be achieved, i.e., a process that is subordinated to a conscious objective. Just as the concept of a motive corresponds to the concept of an activity, so the concept of an objective corresponds to the concept of an action" (87, p. 104). Leontiev thus defines an action as a goal-oriented process that is activated not by its objective but by the motive underlying the activity that the particular action realizes. A characteristic trait of actions as opposed to activities is the non-correspondence of motives with objectives (84; 86). Leontiev defines operations as methods through which actions are carried out. Operations thus correspond not to motives and not to the objectives of actions but to the specific conditions within which the objective is defined (83; 88). Operations are made up of actions: "...When the objective of an action is incorporated into another action as a condition for its execution, the first action is transformed into a method for carrying out the second, into a conscious operation" (86, p. 298).

Leontiev also introduced the concept of the significance that activities (actions) possess for subjects. He views this as the relation of motives to objectives (83, p. 82). In the given context, significance appears as a relation between two things carrying out specific functions within an activity and operating as structural elements of that activity. Significance, he writes, appears as a relation that is actually realized by the subject's life and activity (*Ibid.*, p. 81).

Leontiev emphasizes the instinctive-biological nature of activities among animals, and shows that this determines the narrowness of their psychological reflection of the reality that surrounds them. Everything that is not associated with the biological needs of animals is not reflected by them and does not exist for them—"Animals do not possess stable reflections of reality that are *objectively* goal-oriented" (*Ibid.*, p. 56). This specific feature of their psyche is explained by the structure of their activities. The element that guides the activities of animals always corresponds to motives. Hence animals do not engage in actions. The relation of an animal to an object cannot be separated from the object and does not exist by itself. This also explains the absence among animals of genuine joint activities characterized by a conscious division of functions.

The structure of human activities is altogether different. Labour as a specifically human activity is characterized not only by the use of instruments but by collective efforts as well. The relation of a man to the world is mediated not only by instruments but also by the activities of other persons with whom he enters into production relations (269; 270).

It is the division of labour functions among several persons that first creates actions. That which motivates a particular person to initiate an action may be achieved only as a result of the corresponding actions by each participant in collective labour. Viewed individually, each action does not attain the objective and does not possess a vital significance for the corresponding individual. Social conditions of activity thus require the development of new forms of the psyche that make possible a reflection by each individual of the relation between the objective motive underlying the action and its object, that is, the immediate objective. Exactly this form of the psyche that makes such a relation realized by man as his own relation Leontiev calls reasoned or thinking human consciousness. Thus, "together with the appearance of actions, that principal 'unit' of human activity, the fundamental 'unit' of the human psyche also appears, which is social in nature—namely, a reasonable meaning for man of the objective towards which his activities are directed (83, p. 68).

Such a separation for the subject between the object of activity and his relation to that object leads to a situation in which objects begin to assume a stable relationship to the collective's needs and acquire specific meanings that generalize and crystallize social experience and record it in language. For man meaning objectivizes the significance of what is reflected (*Ibid.*, pp. 79-80).

Leontiev poses in a fundamentally new way the problem of arriving at a psychological characterization of consciousness. The position of traditional bourgeois psychology is that within consciousness one should study only that which it contains, namely, individual psychic phenomena and their mutual relations. As does Vygotsky, Leontiev considers that the features that distinguish consciousness do not merely relate to individual psychic phenomena and processes. Consciousness possesses its own psychological characteristics, namely, a specific internal structure that is influenced by the nature of the subject's external practical activities. Thus, in identifying the specific features of consciousness, the author moves beyond its internal boundaries and overcomes the closure of consciousness within the subject itself (such closure is characteristic of bourgeois psychology). This makes it possible to show the manner in which being determines consciousness in the context of concrete psychological problems. "The actual explanation of consciousness lies... in social conditions and the modes of activity that make consciousness necessary, that is, in labour activities" (88, p. 29).

Having pointed to meaning and personal significance as the major "elements" underlying the internal structure of consciousness, Leontiev shows that in the process of historical development their mutual relations which reflect the particular objective relations of a man to nature and to other persons that develop in different socio-economic formations, produce different structures of consciousness.

Such a view of the psyche as a form of an organism's vital activities that emerges and develops in response to changes in conditions of existence has permitted Leontiev to bring the psyche out of a closed circle within the subject and to understand its relation to man's external activities.

Initially the psyche and consciousness were components of the practical activities of individuals and could not be viewed independently of such activities. Gradually the process of a division of labour led to the appearance of mental and physical labour. In the case of mental labour it is the overall activity that acquires a psychic form, rather than individual elements of that activity and component actions. After becoming distinct in the course of practical activities, psychic processes subsequently acquire independent motives, i.e. are transformed into specific types of activity (83).

In other words, external, practical activities are internalized and acquire the form of internal *ideal* activities. Yet, while they assume a psychic form and become relatively autonomous, they do not cease to be activities, i.e., processes directed at solving vital problems emerging in the course of the subject's interaction with the world. Psychic activities do not become purely spiritual activities that are fundamentally opposed to external, practical activities. This made it possible for Leontiev to overcome the dualistic juxtaposition of internal activities, activities of consciousness, and external activities, and to show that the process of arriving at conscious awareness and external activities are *two forms of the same thing,* namely, of activity, rather than two distinct things. In such a context one of these forms is produced by the other or derives from it. These two forms are related with each other through mutual transitions and mutual transformations, and this represents the most important and effective expression of the integral unity of the psyche with activities. Both these forms of activity "bind man to the external world, each in a different way. That external world is then reflected in his mind" (86, p. 313). "Both are processes that have either acquired significance or have such a potential. The indivisibility and integrity of man's life which manifests itself in two forms—material and ideal—is expressed in their joint existence" (83, p. 99). The integral unity of external, practical activities and internal, psychic activities is also expressed in the fact that both possess a similar structure. Leontiev notes that in the case of both psychic and practical activities one should distinguish the activity, action, and operation. The common structural properties of external activities and psychic activities are what makes it possible for mutual transitions and mutual transformations to take place. Internal activity continuously incorporates individual external actions and operations, while external, practical activities incorporate internal actions and operations of reasoning (83; 86).

Traditional bourgeois psychology has continually emphasized only the dependence of external activities on internal ones, of practical activities on psychic activities. Leontiev posed the problem concerning the reverse dependence, namely, the dependence of internal, psychic activities on external, practical activities. He has shown convincingly the primacy of external, practical activities both in phylogenesis and ontogenesis. That idea has brought Soviet psychology to the threshold at which it can realize Marx's well-known proposition to the effect that "the ideal is nothing else than the material world reflected by the human mind, and translated into forms of thought" (268, p. 29).

Thus the subject of psychology was shifting from the isolated psyche to reasoned activities whose structural elements express themselves in an external material form as well as in an internal, psychic form. Psychic activity is merely a specific type of human activity whose origins are linked to the external material world as a point of departure. In a recently published work, Leontiev states explicitly that "independently of the form that they assume activities are incorporated into the object of psychological science, even though this is in a very different way, of course, than that in which they enter into the object of other sciences" (88, p. 12). Such an approach to the subject implies major adjustments in the path followed by the development of psychological science. In the past it always in fact accepted a juxtaposition of the external and the internal and of the material and the ideal as a point of departure. Now, however, it came to "be based on the actual unity of the subject's psyche and activities and to study their internal interrelations and mutual transformations" (86, p. 27).

The studies of Leontiev also contain a further development of an historical and social approach to man's psyche. In particular, he noted that in the case of man one should distinguish not two, but three types of experience. While animals possess both an inborn experience that is biologically inherited and an individual experience that is superimposed upon it, man possesses still another type of experience, namely, that of social-historical practice, which he acquires during his life, and which represents the experience of mankind. It is through this particular process, which differs in its mechanisms, that man develops specifically human capacities. Leontiev emphasized that that experience should not be confused with individual experience in the narrow sense of that term. It differs from the latter not only in its content but also in terms of the fundamental mechanism through which it is acquired.

Later, in the 1950s Leontiev proposed a hypothesis concerning the "functional organs of the brain", namely, that systemic processes which are formed on the basis of special brain "associations" are the physiological mechanism of higher, specifically human psychic functions. These "associations" emerge and are consolidated during a person's lifetime, and play the role of organs for these psychic functions. The theoretical significance of that hypothesis lies in that it makes it possible to overcome a simplified differentiation between what is biological in man and what is social and to show man's historical and social nature in its integrated form.

That particular theoretical approach has greatly influenced experimental studies. A number of distinct branches of these studies have developed under such persons as L. I. Bozhovich, A. V. Zaporozhets, P. I. Zinchenko, D. B. Elkonin and others. This led not only to the identification of a clear psychological structure encompassing man's activities but to a psychological characterization of each element of that structure. Individual psychic processes were studied in relation to their position within the structure of activities and in relation to the human significance of these activities (36).

These studies have played a major role in overcoming subjectivism in experimental psychological studies, and in making clear the dependence of the psyche on the subject's real life in the context of specific types of activities. In particular, learning activities were studied as a major type of human activity. It was shown that only those elements are consciously perceived in the course of learning that occupy the structural position of an immediate objective for particular actions within the given activity. This has made it possible to understand in a new way the principles underlying conscious, active, and visually tangible forms of learning. Similarly, the problem of encouraging the development of specific psychic functions (such as memory and attention) was now perceived in a new way. In order to make a student attentive to a particular object it is necessary to formulate problems in whose solution that object would occupy the structural position of an objective within the student's corresponding activities. This problem, Leontiev observes, concerns "not characteristics of the child's attention as a certain capacity of his consciousness but the characteristics of his activities" (84, p. 14). It is true that such solutions are possible only in those cases in which attention has already emerged as an internal activity and when the task is merely to direct it to a particular object. This does not eliminate the problem of developing a new internal activity, and Leontiev, therefore, also raises the problem of finding ways to encourage new internal activities. It is not sufficient, he notes, to merely formulate the corresponding tasks. Like Vygotsky, Leontiev sees the principal means in joint activities of adults and children. In such a context, he adds, adults must externalize the required activity, while children must carry out that externally expressed theoretical activity within themselves. Since he believed that even then the desired result may not always be attained, Leontiev pointed to the need for relying on visually tangible elements, that is, real objects that serve as external supports for internal activities. In particular, it is important to note that Leontiev draws attention to the importance of relying "where possible on actions whose form for the learner is external" (*Ibid.*, p. 15).

Leontiev thus not only formulated the thesis that the psyche represents a transformation of external activities, but also turned his attention to the manner in which this is realized in the process of ontogenesis. Subsequently, P. Ya. Galperin and his associates turned to systematical studies of that problem.

By the end of the 1940s, the studies of Vygotsky, Leontiev, Rubinstein and of their associates had thus produced the three fundamental principles that constitute the foundations of Soviet psychology, namely, 1) an activities-oriented approach to the subject of psychology; 2) a recognition of the social nature of man's psychic activities; 3) a recognition of the integral character of psychic activity and of external, practical activity.

§ 2. The Fundamental Principles of Soviet Psychology

1. An Activities-Oriented Approach to the Subject-Matter of Psychology

That principle means that the psyche is understood not as a manifestation of consciousness but as a form of the subject's life activities that are concerned with the specific problem situations arising in the course of his interaction with the world. Man (the subject) appears as an active element rather than a simple container of psychic elements. He engages both in external, practical acts and in psychic acts. The psyche is not merely an image of the world and a system of representations, but an activity, a *system* of actions and operations that are integrated through a common motivation and objective.

Such an activities-oriented approach to the psyche greatly alters the subject of psychology. For rather than studying individual isolated psychic functions (such as attention, will, emotion, etc.) psychologists must now study a system of activities. Within activities individual functions occupy specific structural positions and carry out some particular functional role. It follows that the principles that govern activities are wider than those that govern individual elements of such activities and are more than the sum of the latter. In other words, the subject of psychology, namely, activities, is systems-oriented by its nature and must be studied as a system. This is also why an activities-oriented approach to the psyche cannot be applied simply through a replacement of individual terms, such as "the activity of attention" instead of "the function of attention", "emotional activity" instead of "emotional function", etc., since individual functions do not constitute activities. The fundamental difference between an activities-oriented approach to the subject of psychology and other approaches lies in the following: the object of analysis is the actual process of interaction of man with his environment and this is seen in its integral nature as a process related to the solution of specific tasks. Earlier approaches to that system of activities selected individual elements and analyzed them in isolation from that system. The basic flaw of a subjective-idealistic approach to psychology lies in its separation of man's psyche from his real life and his activities, while, at the other extreme, behaviourism eliminated the psyche from real behaviour and viewed the latter as an aggregate of external responses.

At the psychological level activities are units of existence that are mediated by "a psychic reflection, whose real function is to orient the subject within the world of objects" (88, p. 82). A major characteristic of activities thus concerns their *orientation on objects* (on some specific material or ideal object) and its *subjective nature* (they are carried out by specific persons).

The subject-matter of psychology has also greatly changed in another respect: psychology is no longer expected to study only psychic activities—that is the extreme case. In a typical situation both psychic and non-psychic components of activities are jointly present which may, moreover, also change their form in the process of functioning.

An activities-oriented approach to the subject-matter of psychology has led to a reformulation of the unit of psychological analysis. Generally, for any process the unit of analysis must retain the specific properties of the phenomenon being analyzed. In this connection, Vygotsky emphasized that the psyche should be divided not into the simplest units, but into units that are specific to it, within which all its qualities and properties continue to exist in their simplest form. He noted that a further decomposition into still simpler elements produces a loss of the specific properties of the phenomenon being analyzed, and thus of the specific characteristics of that science (27). "If, for example, we wish to explain why water extinguishes fire," Vygotsky wrote, "we must not decompose water into its elements—for hydrogen is itself combustible, while oxygen contributes to combustion. It is only if we are able to replace an analysis that decomposes the integral phenomena into its elements by *an analysis dividing complex integral units into relatively simple units* that can no longer be decomposed and that represent the integral nature of the whole in the simplest possible form—only then can we hope that our analysis will bring us to a satisfactory solution of the problem" (*Ibid.*, p. 471).

Since psychology studies activities their analysis must be carried out in terms of units that retain all specific characteristics of activities. *Actions* constitute such a unit. They possess the same structure as activities, namely, objectives, motivations and the objects to which they are directed, and a specific set of operations through which actions are carried out, patterns that guide the actions of subjects; and are processes that relate to his (subject's) life activities. Finally, both actions and activities are subject-related, i.e., belong to the subject and are always activities of specific individuals.

The selection of actions as elementary units of psychological analysis does not imply a neglect of images. Like operations, images are elementary components of psychic activity in which the specific characteristics of the psyche as an activity are no longer present. The approach that is being considered therefore requires that images be studied as elements of actions and activities rather than by themselves. Both sensory and conceptual images occupy a structured position within a subject's activity, namely, that of an object of activity, or a pattern intended to guide actions. An analysis in terms of actions does not lead to a neglect of images, even though it does not view them as autonomous elements that may engage in direct interactions.

Images are related to actions and operations in several ways. First, actions are means for forming images. Neither abstract nor sensory images may develop without a corresponding action on the part of the subject. Images are always results and outcomes of specific activities. Perceptions as sensory images result from acts of perception and from the action of "perceiving". Similarly, concepts are products of thought. Second, operations constitute the psychological mechanism of images. The actualization of an image and its reconstitution by a subject is always an outcome of those operations (perhaps instantaneous) from which the image derives and these operations are integral parts of that image (33). Finally, the use of images in the process of solving different problems also takes place through their inclusion into specific actions.

Thus, even though the relation between images and actions is a bilateral one, actions play a leading role. Images without actions on the part of the subject can neither be formed, nor reestablished, nor utilized. It follows that *the formation of images may be regulated only through actions.*

The view that actions form the elementary integral unit of analysis in the case of activities was first proposed by Leontiev (cf. for example, 82) and then by Rubinstein.

In explaining the grounds for selecting such a unit of analysis, Rubinstein observed that an understanding of the diversity of psychic phenomena in terms of their essential internal interrelations "required above all that the particular 'cell' be found, within which one may uncover the beginnings of all elements of psychology in their integral form" (142, p. 173). He adds that it is necessary to find an integral psychophysical unity that will contain all basic elements of the psyche in their real mutual interactions within the context of the specific material conditions and mutual interactions between the individual and the external world. "... Any action forming a unit of his activity is such a cell" (*Ibid.*). Since they relate to both practical and theoretical activities "actions as 'units' of activity result from specific *motivations* and are directed at a specific *objective* when they are viewed in terms of their *psychological contents*, and are *solutions* to *tasks* confronting individuals when they are viewed in relation to the conditions within which such objectives are reached" (*Ibid.*, p. 174).

In Soviet psychology the recognition of actions as integral units of psychological analysis has thus been accompanied by a recognition of the need to rely on an activities-oriented approach to the subject-matter of psychology. In spite of a wide acceptance of such a view of the psyche, actions have not been widely employed as basic units of analysis in concrete psychological studies. Beyond recognizing that the process of learning is an activity it is now important to analyze it in terms of specific actions.

2. The Social Nature of Man's Psychic Development

Man's social mode of existence has produced a situation in which human progress came to be determined by social rather than biological principles of regulation. The experience of man as a species is no longer defined through the mechanisms of heredity and has come to be structured in specifically social ways, in the products of material and spiritual culture. The development of individuals is no longer the result of an unfolding of the experience of their species generated internally through heredity, but of an *assimilation* of external social experience that is embodied in means of production as well as in such objects as books and in language. Man is not born with already developed thought processes and with knowledge of the world nor does he discover anew the logical principles that govern thinking and those laws of nature that are known to society. He acquires this by assimilating the experience of earlier generations. Of course, man then adds to this experience but he does this only after assimilating the experience that is already available in society.

The assimilation of the experience of earlier generations has thus come to play a determining role in the development of individuals. Education and training are specially organized forms of joint activities of members of the older and of the younger generations that permit the latter to assimilate the experience of preceding generations. This does not at all imply, of course, that natural capacities attributable to hereditary mechanisms have ceased to play any role at all; on the contrary, they operate as necessary conditions for man's psychic development. In the words of Zaporozhets and Elkonin "One must be born with a human brain to become a human being" (64, p. 8).

Education and training, on the one hand, and the totality of inborn anatomic and physiological characteristics, on the other, are phenomena of a different order and they should not be viewed together. The first are the source of psychic development while the second are a necessary condition for such a development.

It was Vygotsky (23; 26) who contributed to Soviet psychology the idea that education and training are the source of man's psychic development. More specifically he distinguished two levels of development of a child's potential, namely, the *level of actual development*, which has been produced by already completed cycles of development, and the *zone of potential development*. This refers to the process of becoming which represents the current development's immediate future.

In viewing instruction as a source of development one should identify within it the specific link that is directly responsible for such an effect. Vygotsky emphasized that this is the *contents* of assimilated knowledge, and that the selection of new contents should be guided by zones of potential development rather than by the current level of development. Otherwise instruction will follow actual development rather than guide it.[1]

But even knowledge bearing on zones of potential development results in effective development (and in effective knowledge assimilation) only if students engage in cognitive actions that adequately correspond to this knowledge, i.e., that are directed at uncovering their essential properties. In particular, such a process of instruction cannot be merely limited to social interactions between teachers and students. The students' activities must be directed to the world of things, without which knowledge relating to the contents of the instruction process cannot be transmitted. In other words it is not possible to transmit accumulated knowledge about the world if one neglects that world and neglects the practical activities of those to whom this knowledge is transmitted. The older generation cannot transmit available knowledge to the younger generation through a direct interaction of the consciousness of each or else simply through a verbal communication.

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[1] For an analysis of L. S. Vygotsky's approach to interactions between instruction and development see D. B. Elkonin (190).

The founders of Marxism-Leninism have emphasized that a person's reflection of the world develops in the course of his active influencing the world (260). This means that all ideal forms of wealth accumulated by mankind and given the form of systems of scientific concepts, principles, and established thinking procedures, cannot be transmitted to the next generation in prepared form through some "transplantation", as it were, from one head into another. It can be assimilated by each new generation only with the help of its own activities directed at the world of those things concerning which knowledge is to be transmitted. Attempts to transmit new knowledge directly in verbal form, through verbal communication alone, while neglecting the world of things and of actions, imply a philosophical view of the psyche in which it is a reflection of the consciousness of persons rather than of the external world.

The role of the older generation is to organize activities of the younger generation in relation to the world of things in such a way as to uncover before them those aspects and those principles that must be assimilated. Thus it is only through a contact with the world that each new generation receives knowledge about the world. But the knowledge that then unfolds is not newly developed knowledge. Rather it is transmitted by the older generation with the help of things and through a special organization of activities of the younger generation in relation to things.

The effects of both education and development are a direct outcome of student activities that link them to the external world. Their nature and also the extent to which they are regulated by teachers constitute the principal basis for improving the quality of knowledge-assimilation and enhancing the developmental effect of education.

It follows from these observations that aside from an aggregate of social material and ideal objects older generations also transmit to the younger generation systems of socially developed methods for interacting with those objects. Each object in a society plays a socially structured function and is associated with a specific form of activity. A person will be able to employ specific objects in accordance with their function only after mastering that procedure. Thus, a child begins to use a spoon as an "instrument for eating" only after learning to hold it correctly, that is, after mastering the procedure for acting with a spoon that has been developed by his society. Similarly, it is only after mastering the corresponding logical procedures and forms of activities, including a specific system of thought operations carried out in accordance with specific rules, that man employs concepts for classifying objects.

Actions thus operate as leading components in the process of assimilating experience. Without assimilating them the world of material and ideal things remains closed to man.

In referring to the process of assimilation, A. N. Leontiev emphasizes that in order to master "the product of human activity it is necessary to carry out *activities* that adequately correspond to those which the given product embodies" (85, p. 11). His proposition that activities are embodied and objectified in objects should not be understood in the sense that activities are located within an object in an already developed form as in some social piggy bank: they are not there and could not be found there. Its meaning is that the nature of actions with an object is predefined by that object's characteristic features. An object carries, as it were, a label defining the method in which it may be employed. The actions and operations that are needed to master any object are not only non-present within the object itself but "a capacity to carry out these operations cannot be developed by a child under the influence of the instrument [object.—*N. T.*] itself" (*Ibid.*, p. 12).

The works of Leontiev emphasize that the existence alone of objects of material and spiritual culture is not sufficient for the operational aspect of human experience be assimilated. Engaging in appropriate activities in relation to these objects is the first necessary condition for assimilating social experience, but *social interaction* with the older generation is also required. "While objectively these operations are embodied in instruments, a child subjective-ly perceives them as being *contained* in these instruments. He is able to discover them only because his relation to the world of things is mediated by his relations to persons. Adults show children the methods that are needed to employ instruments and help them to employ them in appropriate ways, i.e., they *construct* instrumental operations within children" (*Ibid.*).

In showing the specific characteristics of social procedures for consolidating experience Leontiev notes that human "properties and capacities acquire an objective, thing-related form" (86, p. 361) and the activities of earlier generations are embodied in the social product (85, p. 11). He does not explain more precisely, however, which specific activity is embodied in the product: that which led to its (object) creation or that which is carried out with its help and is the reason why that object was created. In terms of their contents these are different types of activities: the activities that produce a spoon, for example, differ substantially from those in which that spoon is employed as an instrument for eating. Leontiev does not distinguish between them because that distinction is not significant within the logic of the problem that he considers. Both types of activities are embodied in social objects in corresponding forms.

This is the reason, however, why Leontiev and his disciples are sometimes accused of reducing the development of human capacities to the assimilation of the particular object-oriented methods of action that have developed in society and of neglecting the importance of the processes through which these objects are created (147; 157). The process of creating social objects is also associated with the assimilation of object-oriented methods of acting, but in that case the objects in question will be not those that are produced (the final goal of activities) but those from which they are created. The operations underlying these two types of activities will also differ. Naturally, these two essentially distinct types of actions should also be distinguished in the process of teaching: having taught a child to employ a spoon we will not have taught him how to produce it; and having taught a person to employ the laws of science, we still will not have taught him the methods that led to their discovery.

The process of identifying actions that are appropriate to social objects (material and ideal) is a serious task for adults as well as for children. This relates, moreover, both to methods of acting that are needed to create social objects and to methods of acting in utilizing these objects.

Before any social object or any method for producing and utilizing it becomes a social legacy it operates as a personal and individual capacity. It becomes a social legacy only after a specific mode of acting with that object is associated with it, and when it is created in order to carry out specific functions within a society. Transitions of objects (products) and of methods of acting from the individual sphere to the social sphere occur in different ways.

Because in the case of objects of material culture corresponding modes of action are expressed externally they lend themselves more readily to verbal fixation. In the case of objects of spiritual culture the process of identifying and objectifying adequate modes of action proceeds in much more complicated ways. Let us consider the example of fine arts. Paintings and sculptures are intended to produce aesthetic pleasure in man. But this requires that man assimilate adequate modes of action in relation to them, and that the older generation help the younger one in achieving this. The content of activities resulting in the discovery of the artistic content of objects of art is still insufficiently understood, even though these objects have appeared a very long time ago. Of course, in that case as well, the older generation does help the younger one to some extent in mastering the necessary activities, but an insufficient understanding of such activities often produces situations in which teachers either fail entirely in developing an adequate mode of action, or else these modes develop over a very long time through a gradual guidance on appropriate actions and through prolonged practical experience.

Since in such cases the mode of action does not appear as a special object to be assimilated (is not the goal of the action within the corresponding activity in terms of the analytical scheme of Leontiev) it is insufficiently recognized even when it does develop. It may, therefore, not be freely actualized and hence objectified for purposes of transfer to other persons. Such situations are quite frequent. The older generation has mastered activities that are appropriate to particular social objects, but does not consciously perceive their contents. For example, the mathematician may prove a theorem through the method of disproving the converse proposition. But he may not be able to point to the content and sequence of mental actions and operations on which he relies, and will therefore not be able to purposefully develop similar activities among his students.

To infer from a social product the activities that lead to its creation is by no means an easy matter. As Marx observed, the process of labour vanishes within the product of labour. A given product, moreover, may be created through activities that greatly differ from each other. This is why many production secrets vanish with the death of persons who mastered them. While the product remains and continues to embody, in a certain sense, the activities of its creator, it is by no means a simple task to reconstruct these activities.

In cases in which modes of action are known, they have been objectified in verbal form. Many of them are described, i.e., consolidated in a specific social form in which it is stored for future generations.

Thus modes of action that have emerged in society and that are appropriate to the creation of specific social objects are only suggested by those objects rather than constrained within them. Such actions often exist as components of the practical and theoretical activities of persons, and are partly objectified and recorded with the help of language.

Actions that are required today but are not yet objectified cannot be developed within the younger generation in a conscious and goal-oriented way. In order to establish that content an analysis is needed of those social objects (material and ideal) with which they are associated, and also of the activities (material and ideal) of persons who control them. Only objectified actions may serve as objects of assimilation and be consciously assimilated.

3. The Integral Unity of the Psyche and Activities

While that principle is recognized by all Soviet psychologists it is interpreted in different ways. In most cases it is understood in the manner described by Rubinstein: activities not only express the psyche and consciousness but also develop them (142). This view has been presented in texts (123; 124; and others). It has already been noted, however, that a simple recognition of the integral unity of the psyche with activities without identifying the specific ways in which they interact does not lead to an overcoming of dualism, that is of a juxtaposition of the external to the internal and of the material to the ideal. It has already been shown that the studies of Leontiev have led to the identification of several distinct aspects of the integral unity of external activities with the psyche.

The studies of Leontiev and of his school were above all concerned with understanding activity structures and the dependence of individual psychic processes on their position within activity structures. It was shown that the integral unity of the psyche and external activities derives from the fact that both are activities and that both types of activity possess an identical structure. Another aspect of the integral unity of external practical activities and psychic activities was noted by Leontiev in his proposition that internal psychic activities are transformations of external material activities. Like Vygotsky he has emphasized that it is important to "recognize that the former is a manifestation of the latter and of the latter's structure and laws" (83, p. 97).

According to that proposition psychic activity does not merely develop *in the course* of practical activity but is formed *from* practical activities. Such a conception of the origins of psychic phenomena follows from the Marxist view that psyche is secondary in relation to existence and also from viewing the psyche as an activity. Since psyche is an activity it includes not only ideal objects (representations, conceptions) but also ideal operations. External objects are the primary material source of images (representations, conceptions). External material activities are primary in relation to new psychic activities generally; this refers, moreover, to the subject's own material actions rather than those of other persons, since we are considering the development of ideal *actions* rather than *images* of action.

The development of that principle called for a clarification of the manner in which new internal actions develop, of the specific ways in which they are transformed from external, practical actions, the basic characteristics of actions viewed as units of any activity, and of the specific systems of actions that underlie different types of internal psychic activity. It was Galperin who found answers to all these questions and who proposed a new theory of a stage-by-stage formation of mental actions.

In his studies Galperin relied on the principles of Soviet psychology as well as on experimental studies carried out by Soviet scholars (B. G. Ananiev, V. I. Asnin, E. V. Gurianov, L. V. Zankov, A. V. Zaporozhets, B. V. Zeigarnik, P. I. Zinchenko, G. S. Kostyuk, A. N. Leontiev, A. R. Luria, N. A. Menchinskaya, A. A. Smirnov, B. M. Teplov, P. A. Shevarev, D. B. Elkonin). He pointed to an approach to the further development of the principle of the integral unity of psychic and practical, internal and external activities.

Like Vygotsky and Leontiev, Galperin noted that new types of psychic activity are first assimilated in external—material—forms and are then transformed into internal—psychic—forms (32). Such transformations relate to systems of independent characteristics (parameters). Combinations of qualitative changes in these characteristics constitute a number of stages, and transitions from one stage to the next constitute the process of transformation of external material activities into internal psychic activities. In the course of that process external objects of activity are replaced by their images—representations, conceptions, while practical operations are transformed into mental and theoretical operations.

Galperin's theory has opened the way to concrete psychological studies of psychic activities themselves, and has served as an instrument in developing specific forms and types of psychic activities. He did not limit himself to general propositions concerning activities and did not simply identify actions as units of analysis of psychic activity. Rather he has employed the study of the origin of mental activities (psychic activities) as a method for studying psychic activities generally and formulated the problem of analyzing specific types of psychic activities in terms of the individual mental actions of which they are composed (38).

4. *Principles of Soviet Psychology and the Theory of Learning*

The principles of Soviet psychology represent a particular outcome of a struggle for preserving and developing a Marxist methodology in psychological science, and they require that the process of learning be viewed as an activity. An activities-oriented approach to the process of learning requires that it be analyzed as an integrated system and as a real process for solving the problems that confront socio-historical man who is the subject of such activities.

A person's activities are always responses to a corresponding need and are directed to an object that is able to satisfy such a need. That object stimulates and governs the subject's activity. In the light of such an understanding of activity it is only when it meets a need for knowledge acquisition that learning becomes activity in the proper sense of that word. Types of knowledge towards which the learning process is directed then appear both as the motivation, in which the student's need for learning has become objectified, and the activity's objective. In cases when students do not have such a need they either will not be engaged in learning or else will be learning in order to satisfy some other need. In such a case learning ceases to be an activity since instead of meeting a particular need—the acquisition of knowledge—it merely serves as an intermediary objective. In such a case learning is an *action* realizing some other activity; the knowledge that serves as the action's objective does not serve as a motivation, since it is not knowledge which activates the learning process.

Whatever the nature of the need that is being satisfied through learning it is always met through an action or a sequence of actions. A particular activity may be met through different actions, and conversely, a given action may serve different activities (88). Actions, accordingly, possess a measure of relative autonomy.

The study of learning processes thus calls for two levels of analysis: a) from the point of view of the need that learning seeks to satisfy; and b) from the point of view of the individual actions that constitute it.

An analysis of the learning process in terms of unitary actions differs substantially from both a functional analysis and from an analysis in terms of a behaviourist scheme.

In particular, an activities-oriented approach makes it possible to view learning as a process that is genuinely active on the part of the student. For the latter is seen not as an organism responding to stimuli passively and blindly and subordinating itself to the logic of reinforcement, but as an entity that anticipates encounters with the object of activities and studies it as well as the conditions within which it exists.

Within the context of an activities-oriented approach the process of learning is viewed neither as an actualization and development of some abstract primordially given functions (abilities) relating to thought, memory, attention, etc., as was implied in the old idealistic psychology, nor as a process for developing a system of external responses that are viewed as direct responses to stimuli, as suggested by behaviourism. It is a process of assimilation of various types of human activities by students and hence of the set of actions that brings this about.

Such an approach to learning does not imply that thinking, memory and other psychic processes are excluded from the corresponding analysis. It merely implies a different understanding of their nature, their functional significance and their origin. Because of the social nature of man's psyche men are not born with developed abilities for thinking, remembering, etc. Rather they assimilate these elements during their lifetime by transforming social experience into their own personal experience. In such a context the psyche develops not as a set of abstract functions but as the source of autonomous types of psychic activity or else serves as an element of other types of activity. Thus, for example, while attentiveness does not constitute an independent activity, it contributes a controlling function to other activities (35; 46). Similarly, memory provides a balance between currently actualized actions and both preceding and subsequent actions, i.e., operates as a regulator of the temporal aspect of human activities (96). This means that the process of teaching is concerned with the development of specific types of activities, and above all of cognitive activities, rather than with the development of some abstract functions of memory, thinking, attentiveness, etc.

A perspective on the process of learning as an activity also calls for a fundamentally different view of relations between knowledge, abilities and working habits. Knowledge should not be juxtaposed to abilities and habits which are actions possessing their own specific properties, but should be viewed as a component of such actions. Outside the context of the learner's activities, knowledge can be neither assimilated nor preserved. Similarly, measures of acquired knowledge cannot be viewed independently of actions. To know always means to carry out some activity or action associated with the given knowledge. Knowledge is a relative concept. The extent (quality) of assimilation of knowledge is defined by the variety and nature of activities in relation to which knowledge can operate. Thus instead of two problems, namely, to transfer knowledge and to develop abilities and habits in applying knowledge, the teaching process confronts only one—to develop types of activities that will contain the given system of knowledge from the very first and that will provide for its application within predetermined boundaries.

In accordance with the principle that the laws governing man's psychic development are social in nature, the theory of learning must base itself on the proposition that the development of learning capacities of students takes place not through the development of capacities that already exist at birth, but through an assimilation of those types and modes of cognitive activity that constitute mankind's cognitive experience, which has been either partly or fully objectified and recorded with the help of social means.

In other words the theory of learning must be directed at studies of the principles bearing on the transformation of phenomena of social awareness into phenomena of individual awareness. In those cases in which the required types of actions and ways for carrying them out are not objectified and are not recorded as components of social experience and exist only as facts of individual awareness, the theory of learning must show the way in which they may be objectified, recorded and made accessible to assimilation.

The principle of the unity of psychic and external activities contributes to the theory of learning a fundamental way of shifting approaches to cognitive activities from the sphere of social awareness to that of individual. An approach to psychic activity that views it as secondary, that is as transformed external activity, requires that any new type of cognitive activity be initially introduced into the teaching-learning process in terms of its external form, as a material activity.

The theory of learning must also describe the basic outlines of the process through which external, material forms of cognitive activity are transformed into internal psychic forms.

The theory of learning that does not meet the requirements that follow from the basic methodological principles of Marxist psychology, cannot be expected to provide an effective psychological basis for control of learning processes since such strategies do not correspond to their nature.

§ 3. Instruction in the Light of a General Theory of Control

In cybernetics control refers to the operation of an influence on an object (process) of control that is selected from a wider set of possible influences in the light of a desired objective, the state of an object (process) or its characteristics, that lead to an improvement in the given object's functioning and development, i.e., to a closer approximation to the objective (90, pp. 104-05).

To control does not mean to suppress or impose on the process a course that contradicts its nature. On the contrary, it implies that the nature of the process in question is taken into consideration to the maximum possible extent, and that each influence on the process is applied in accordance with the process's own logic. In control of both the learning process or any other, freedom appears as consciously perceived necessity.

All types of control may be divided into open loop and closed loop (cyclic) control. In the first case control proceeds without feedback and hence without a control of the course of the process by a control system. The second type presupposes both. It is a more effective method of control and is more characteristic of cybernetics.

Closed loop or cyclic control may be carried out in different ways: a) in accordance with the principle of a so-called black box, when the feedback and hence the control of the process respond only to "output" states, i.e., to the final outcomes of the process in question (the causal path leading to the outcome remains unknown); b) in accordance with the principle of a so-called white (or transparent) box. In that case the feedback relation includes information concerning the process through which the final outcome is achieved.

In selecting a principle and type of control it is necessary to take a number of factors into consideration, including the complexity of the controlled process, and the extent to which the principles that govern behaviour are in fact known. Forms of control of the "black-box" type are employed only in those cases in which the desired information concerning the system, the influence of possible perturbances, etc., is unknown. And while individual authors (204) consider that it is control of the "black-box" type that is specific to cybernetic regulation, most authors stress the limitations that derive from such an approach and the need to a transition, whenever possible, from an analysis of the control system at the macro level (in accordance with the principle of a "black box") to an analysis at the level of a micro or "white-box" approach. In particular, it is noted that it is only when knowledge is available concerning a system's structure and its transition states that it is possible to arrive at an optimal control of systems (94).

In the case of education and training, the control "object" is the human personality together with different types of human psychic activity. In order to convey some notion of the complexity of these processes it is sufficient to note that the largest number possessing some real significance is the number of possible states of the human brain.

In considering control principles it should be kept in mind that no unique correspondence exists between influences experienced by persons and their external responses. In particular, substantially different types of learning activities may produce identical answers on the part of students in solving a mathematical problem: in one case it may be the result of memory and in another, of independent thinking. It is also possible to obtain a correct result through erroneous actions.

Since the principal task of instruction is the development of reasoned approaches to cognitive activities we must recognize that in this particular case control in accordance with the principle of a "black box" will be ineffective. Pedagogics must seek approaches to the control of cognitive activities as a whole rather than only of its outcome.

Individual actions of students are governed not only by current influences and by the current state of their psychic activity, but by their entire earlier history of learning as well. Beyond this, new intermediate variables develop in the course of learning that contribute additional elements of complexity. In control of learning activities it is therefore important to consider all available psychological knowledge concerning such activities in order that these may be optimized. ilt is true, of course, that both psychology and the pedagogics are still some distance from a full understanding of the principles that govern cognitive activities. But these are also far from being a "black box": there exists a considerable aggregate of knowledge concerning their functioning and development.

These observations indicate that with regard to education and training consideration should be given to closed loop or cyclic forms of control, based, whenever possible, on the "white-box" approach. This can be made possible by meeting the following system of requirements, which are derived from cybernetics: 1) the objective of control must be specified; 2) the initial state of the controlled process must be established; 3) a programme of control actions introducing major transition states within the process must be designed; 4) access to information concerning the state of the controlled process must be organized in terms of a system of parameters, i.e., a systematic feedback relation must be organized; 5) information received along feedback channels must be processed, and correcting (regulating) operations must be designed and implemented.[1]

These specifications call for the development of two types of control (teaching) programmes: basic programmes and correcting (regulating) programmes. The basic control (teaching) programme is designed before the control system begins to function. Its development takes into consideration the initial state of the controlled process and its qualitatively specific transition states (in the case of learning this refers to the major stages of the knowledge-assimilation process).

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[1] Robert Glaser (234) was one of the earliest authors who analyzed the teaching-learning process as an integrated system. Subsequently, a number of studies have elaborated upon that approach (see, for example, 242; 308; and others).

The regulating (correcting) programme is developed in the course of the control process (teaching). It is based on analyses of the data received along feedback channels.

Let us consider these general specifications as they are applied to the teaching-learning process.

1. The Objective of Control (Instructional Objective)

Regulation is always goal-oriented or purposeful in nature. In some cases its goal is to support the controlled process (object) or else to maintain it either in an exogenously specified state or within specified boundaries. In other cases the objective of control is to change the state of the controlled process and bring it to a desired state. It is the second case that applies to instruction: the task of instruction is to bring about specific changes in the cognitive activities of the learner.

At first the instructional objective must be analyzed at the macro level, by listing all those changes that must be effected in the students at the given stage of the learning process, or else as a result of studying the given subject. Several factors define the specific contents of instructional objectives. Above all these are the socio-historical and class conditions within which the person in question lives, the concrete possibilities that are available at each stage of the learning process, and the nature of the tasks for whose resolution he is preparing himself. Next a micro-level analysis is needed. In specifying instructional goals at that level the corresponding analysis must be carried to the point at which particular types of cognitive activities to be developed are indicated and such pertinent characteristics as the degree of generalization and the level of automation. It is important to recognize that teaching is linked with all aspects of an individual's personality, and that aside from introducing changes in his cognitive activities it also influences their ethical, aesthetic and other activities.

2. The Initial State of the Psychic Activities of the Learner

The state of preparedness of the learner encompasses not only intellectual and cognitive types of psychic activity, but other aspects of his personality as well. As in the case of instructional objectives, an analysis of the initial state of his psychic activities must be carried out at two levels: 1) to establish the extent to which the psychic development of the learner matches the objectives that are specified for the given stage of learning or else in studying a particular subject; and 2) to establish the extent to which he possesses the specific type of knowledge and is engaged in the particular cognitive activities that are needed to develop the indicated type of cognitive activity.

Naturally, a diagnosis of the general level of development of the learner is first carried out, and this establishes the degree to which he is in fact prepared for learning at the given stage or to study the specific subject. In establishing the presence of prerequisite forms of knowledge and abilities two cases may arise: a) all required knowledge and abilities are in fact present; b) a part of the required forms of knowledge and abilities have not been developed or not sufficiently developed in terms of the particular indicators that the assimilation of new knowledge and abilities requires. In the first case, the teaching programme provides for the development of only those new forms of knowledge and abilities that are inferred from the instructional objective, while in the second, the missing elements are first developed, and only then does a shift to specified instructional objectives take place.

An analysis of the initial state of psychic activity may also be carried out in order to establish the specific characteristics of the learner. The resulting findings are then employed to design individually adapted teaching programmes that take the specific characteristics of the psychic activities of the student into consideration. In such cases, the role and forms of individual adaptation refer not to the contents of the teaching programme but to its mode and speed of exposition.

3. *Basic States of the Knowledge-Assimilation Process*

The effectiveness with which teaching objectives (desired final states) are attained depends on a knowledge of the nature and sequence of major intermediate states (51). Accordingly, the learning process control programme must provide for the movement of types of psychic activities, which are to be developed, through major qualitative stages. It is only by analyzing the specific principles of the controlled process that the contents of these stages and their sequence may be identified. In our case this implies a knowledge of learning theory. It is the specific properties of individual stages in the process of knowledge assimilation that define the basic teaching programme and, to a large extent, the regulating programme as well.

4. *Feedback in the Teaching-Learning Process*

The concept of feedback relations in cybernetics is understood in a number of ways. Some authors refer to it as a feedback influence of a process upon itself: it influences the external environment, which in its turn then begins to influence it in a new manner. The feedback relation is said to be *positive* when that influence produces increasing values of the variables being regulated and is called *negative* when it causes them to decline. We find such an interpretation of feedback in works by S. Beer (204), P. Cossa (214) and others. In particular, Beer writes that the meaning of a feedback relation derives from the fact that "the move [of variables.—*N. T.*] towards freedom from constraint itself operates the control: the two things are inexorably coupled" (204, p. 29). An essential characteristic of such an understanding of feedback is that the current course of the controlled process acts upon its future course. Such a meaning of a feedback relation includes not only the information concerning the current state of the controlled object, but the subsequent corrective action by the regulating object as well.

There is another interpretation of feedback in which its contents are limited to the stage at which information concerning the course of the controlled process is produced.

Thus, for example, N. Wiener states that the function of feedback relations is to record whether a certain command (programme) is executed or not executed (324). Liapunov and Yablonsky interpret feedback as information concerning the current state of a controlled system that is being channeled into a controller (95). A similar interpretation of the function of feedback may be found in a number of other studies.

A number of facts provide support for such a view of feedback: in particular, the first interpretation of feedback assumes that direct mechanical linkages exist between regulated objects and regulating ones (a type of Watt's governor). I. B. Novik (110) rightly observes that the presence of such linkages is not a characteristic of cybernetic control. The specific characteristic of cybernetic control is that it is carried out with the help of signals conveying a certain information. But this does not necessarily imply that direct linkages exist between controlled objects and control objects. This refers, for example, to cases in which the controlled object is located at a great distance from the control object.

Second, the functioning of the two stages of control that are present in the first interpretation of feedback may also be separately organized. Indeed, control activities are not always inferred solely from current information concerning the state of controlled objects. Control is often effected in the light of information that has been received earlier and that has been accumulated within the controller's memory. In such cases the acquisition of information concerning the course of a process within the controlled system is separated from regulating (correcting) activities by such distinct stages as the taking of decisions and the design of implementation algorithms. The transmission of information from controlled objects and subsequent correction process are thus by no means always directly linked. Beyond this, there are cases in which delays are deliberately introduced in individual stages of the control process: the collection of information concerning the controlled object may be separated in time from the process in which that information is employed in serving control objectives (8). Finally, corrections are not always needed in the course of control: in cases in which the controlled process is proceeding in accordance with a desired programme the controller will not exert any additional influences. In such cases, the second stage of control will be missing but the acquisition of information concerning the progress of control does take place. In view of these observations, we will limit the meaning of feedback to the acquisition of information concerning the course of regulated processes.[1]

We will view the correction of the assimilation process made on the basis of the utilization of this information as one of the distinct stages of control.

In order to apply feedback to the learning process the following two problems must be solved.[2] First, the contents of the given feedback relation must be determined. This refers to the specification of a set of controlled characteristics on the basis of both instructional objectives and of the selected psychological learning theory that provides a basis for designing teaching programmes. The relevant general rule is that those major independent process characteristics should be regulated and their aggregate changes will bring about a transition from one qualitative state to another.

Second, the frequency of feedback must be established. It is generally accepted in cybernetics that the effectiveness of regulation activities is proportional to the frequency of control activities. An ideal case is one in which a so-called monitoring driven feedback exists. Attempts to mechanically apply this proposition to learning processes have not been successful, for in principle, in the case of learning processes control operates as a reinforcement function as well as a feedback one. It is also influenced by the student's motivation sphere (168).

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[1] In principle the term "feedback" may be given the first interpretation, i.e., it may refer to both indicated stages of control. But it would then be necessary to introduce a separate term to refer to the stage at which information concerning the controlled object is collected.

[2] The concept of feedback is associated with the emergence of cybernetics (1948). Norbert Wiener introduced that concept on the basis of a generalization of findings relating above all to the field of radio technology and the theory of automatic regulation. But physiologists and psychologists were aware of the need for feedback in the behaviour of animals and in human activities much earlier. In descriptive terms its importance was noted already in the nineteenth century (see, for example, the experiments of G. M. Stratton in 1896 and 1897) (310). This was carried to the level of a theoretical analysis in the studies of E. Thorndike (319), I. P. Pavlov (117), P. K. Anokhin (4), and N. A. Bernstein (10; 12).

5. The Regulation (Correction) of Teaching-Learning Processes

Information concerning the teaching-learning process that is received through feedback channels makes it possible to introduce appropriate corrections. From a cybernetic point of view regulation (correction) may be carried out in three ways: 1) responses to anticipated changes in the situation (in such a case activities that are harmful to the system are anticipated in terms of indirect attributes and an appropriate restructuring of the programme takes place): 2) responses to changes in a situation (programmes are corrected in accordance with changes in conditions bearing on the system's operation: in both, corrections make it possible to avoid deviations in the regulated processes, since this is carried out before changed conditions have time to bring about harmful influences); 3) responses to errors (in such cases there are deviations in the process's course under the influence of particular perturbances and corrections are then introduced in accordance with the nature of the deviations, that is, on the basis of an analysis of the corresponding errors).

In principle, all three methods may be applied to the regulation of learning processes. In the practice of programmed instruction, however, corrections are usually based on the third method, namely, responses to errors on the part of students. Changes are entered into programmes that reflect the nature of such errors and are intended to overcome their effect. In programmed instruction this method of correction is preferred because the corresponding feedback relation can then be based on a single parameter, namely, the extent to which the assignments of students are being carried out. Naturally, when this type of feedback is employed other types of correction are not possible. Their use requires that the content and basic system of characteristics of cognitive activities leading to the particular answer be controlled. In addition, they require a knowledge of the logic that governs the development of these characteristics, i.e., the basic transition states in their emergence.

It should also be noted that the correcting of programmes may be carried out not only when errors have been recorded or are anticipated but also when they are absent, as well as in cases in which there are no signals concerning their possible appearance. Let us clarify this. The specific characteristics of teaching as a regulation system concerns, above all, the circumstance that the regulated object, namely, the learning, assimilation process, is always carried out by a particular person. The complexity and multiplicity of personal factors are so great that they cannot be taken into consideration fully in designing the basic programme. In the context of mass instruction the basic teaching programme may at best be adapted to a certain system of typical characteristics that are appropriate to a specific group of learners. In contrast to this, in the process of teaching particular individuals, certain additional characteristics may be identified that may make it possible for such persons to achieve the specified objective more rapidly. For example, a teaching programme for a given stage of assimilation may provide for a specific number of tasks. For some of the students, however, it may be sufficient to carry out only some of these tasks in order to complete the corresponding stage. Obviously, it is appropriate to carry out a correction of the programme for these individuals by reducing the number of tasks for the given stage and shifting the process of assimilation to the next stage. We thus see that corrections may indeed be carried out in situations in which there are no errors and when the probability of their appearance is, in effect, zero.

The concrete contents of regulating activities are determined, first, by the nature of the information that is received with the help of feedback, and second, by the internal logic of the learning process. Since in pedagogics and psychology there exists a variety of views concerning the logic of the learning process, the manner in which that problem will be met depends on the particular theory that is accepted. As a result, for a given instructional goal, the theory that is selected will define both the specific set of characteristics that are recorded with the help of feedback and the system of regulating activities. The probability of achieving an objective then naturally depends on the extent to which the selected theory corresponds to the actual nature of the learning process.

6. The Control Theory Requirements to Learning Theory

The analysis of instruction as a specific type of regulation shows that the specific characteristics of that process call for a cyclic (closed loop) regulation of the "white-box" type. In order to carry out such a form of regulation a theory of learning must possess data needed to solve the following tasks:

1. A precise identification of the object (process) to be controlled. In the light of the principles of Soviet psychology it is possible to say that this is the process of assimilation ("acquisition", according to Leontiev) of different types of activities by the learner, and above all of cognitive activities.
2. An identification of a system of independent characteristics (variables) describing the object of regulation. A knowledge of such a system of variables is needed both in order to determine the content of information that must be received along feedback channels and to effect correcting activities.
3. An identification of the basic transition states (basic stages) of the process being regulated. It has already been noted that control in accordance with the principle of a "white box" may be carried out only when knowledge is available concerning the transition states of the process under consideration. A knowledge of its major states makes it possible to design a control programme that corresponds adequately to the nature of that process and to the logic of transitions from one qualitative state into another.

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Thus we see that an analysis of the methodological and cybernetic requirements shows that in order to follow the course of development of programmed teaching, a theory of learning is needed that will view learning as the development of cognitive activity on the part of students and that possesses a system of independent characteristics for that activity as well as a knowledge of major stages in its development as transitions from the sphere of social experience to that of individual experience. There is only one theory that meets these requirements, namely, the theory of a stage-by-stage development of mental actions proposed by Galperin in the early 1950s which has been elaborated further by his disciples and followers. We therefore believe it is appropriate to begin a comparative analysis of contemporary theories of learning with a presentation of that particular theory.

Chapter Two

THE THEORY OF A STAGE-BY-STAGE DEVELOPMENT OF MENTAL ACTIONS

That theory views learning as a system of specific types of activities whose execution produces new knowledge and abilities. "Let us agree to denote by learning any activities that develop new knowledge and abilities in the individual who carries them out, or else cause old knowledge and abilities to acquire new qualities" (39, p. 15). In its turn each type of activity associated with learning consists of a system of actions that are integrated by a common motivation and, when taken together, result in achieving the objective of the corresponding activity.

An analysis of learning should begin with an identification of the activity that the student should carry out in order to solve a particular task. Then it is necessary to identify its component actions, and then to undertake a structural and functional analysis of the contents of each.

The central link in that theory are actions that represent integral elementary units of learning activity as well as of any human activity. It is thus at the level of actions that we will analyze the theory under consideration.

§ 1. The Structural and Functional Components of Actions

It has already been noted that the execution of an action by a subject always presupposes a specific *objective*, which is itself achieved on the basis of some *motivation*. Actions are always directed at material or else ideal *objects*. The effecting of actions by a subject presupposes that the latter possesses a specific conception concerning both the action and the conditions under which it is carried out. The *subject* of actions is the carrier of the actions being considered. Finally, all actions include specific aggregates of *operations* that are carried out in a specified order and in accordance with a particular rule. A consistent execution of operations constitutes a *process* of action execution.

In the theory being considered the image of the action and that of the environment within which the action takes place are combined into an integrated structural element which guides the control of action and is called the *orienting basis of actions* (35; 36; 42). This must be distinguished from the system of conditions that are *objectively* required in order that an action be carried out successfully. Such a system of conditions includes: a) the specific characteristics of the objective and of the object of the action; b) the nature and sequence of operations included in the action; c) the specific characteristics of the instruments that are employed (38, p. 29; 39, p. 16). These conditions influence the effectiveness of actions independently of whether or not the student is aware of their importance. Thus, for example, in playing chess the effectiveness of a move is objectively determined by the extent to which it leads to interactions among figures that result in a control of fields on the chess-board.

The orienting basis of actions refers to that system of conditions upon which persons rely *in fact* in guiding their actions. This may or may not coincide with what is objectively appropriate. Frequently a person takes into account only a part of the objectively relevant conditions and occasionally he includes into the orienting basis of his actions others that are irrelevant. For example, in solving the problem "construct four equilateral triangles from six matches without breaking a match" many persons add to the orienting basis of their actions the requirement "carry this out on a single plane", even though such a condition was not in fact specified.

Let us recall (see Chapter One, § 1) that the concept of an activity refers to a process of solving the problem of human existence that is motivated by the particular objective that it seeks to achieve. The action is motivated not by the objective itself but by the motivation of the activity to which it relates. Operations are procedures through which actions are carried out. It follows that the solution of a problem in arithmetic, for example, will be an activity if its motivation and objective coincide. In particular, the addition of two multiplace numbers that the student carries out in the course of solving that problem will be an action, while the addition of units or tenths within these numbers will be operations. Under such an interpretation actions and operations are relative concepts. That which will be an action at a particular stage of learning will be an operation in another. Beyond this, actions may be transformed into activities and conversely. If, for example, a student initially engages in learning without interest and is guided only by a feeling of duty, a commitment to learn, or else an understanding of the impossibility of solving other more interesting problems without first solving the ones in question, then the process of solving each of these problems is an action. But if at some stage he becomes interested in these problems for their own sake, and if a cognitive interest emerges in relation to them, then the process of carrying out the same tasks will become an activity, since the corresponding motivation has now shifted to the objective and has begun to coincide with it. Should these stages be experienced in the reverse order, the student would effect a transition from activities to actions.

Since in the sections that follow we will not consider specific correspondences of motivations and objectives in the solution by the learner of particular problems we will not insist on a rigorous differentiation between processes constituting actions and others that are activities. This does not, of course, mean that we consider this distinction to be unimportant. On the contrary, we fully understand the significance of an interest in cognition for effective learning. Our analysis, however, will be primarily concerned with the level of actions.

In terms of the distinct functions that they perform three components of actions may be distinguished, namely, those that are concerned with orientation, execution and control. Galperin observes that "each human action contains an orienting, executing and control component" (35, p. 34).[1] The orienting component of an action is associated with man's use of the set of objective conditions that a successful execution of the given action requires, and which have been incorporated into the contents of the orienting basis of the given action. The executive component is an action's working part that produces the required transformation in the object of actions (ideal or material). The control component of an action is concerned with monitoring the course of actions and with comparing the resulting outcome to specified reference standards. It makes possible the corrections that are needed in the action's orienting and executive components.

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[1] In some of his studies, Galperin sometimes distinguishes between only two major components of actions, namely, the orienting and the executive one, and then divides the orienting component into sub-components concerned with orienting proper and with control.

These components vary in complexity and in scope. All three, however, must be present simultaneously in all actions since without them actions cannot be carried out. Thus, any human action represents a certain control micro system that includes a "control organ" (the orienting component of actions), an executive organ or "working organ" (the executive component of actions) and a mechanism for monitoring and comparing (the control component of actions).

§ 2. The Characteristics of an Action

"Human actions always occur at some specific level; ... an action always possesses a specific measure of generalization, its operations vary in intensity and they produce various degrees of assimilation" (38, p. 10). Thus, any action by a subject may be described by noting the extent to which each of its principal characteristics is developed. An action's independent characteristics (parameters) include: its *form, level of generalization, comprehensiveness,* and *the extent to which it is mastered* (automated, rapid, etc.) (32; 36).

An action's *form* characterizes the extent (level) to which it is inherent in the subject. It is the principal aspect describing changes in actions as they are transformed from external (material) actions into internal (mental) actions. In short, an action's form characterizes the extent to which it is internalized. In such a context three major forms of action are distinguished: material, that of external speech, and mental. In addition, the materialized form is distinguished, which is close to the material one, as well as the perceptual form, which is intermediate, as it were, between the material (or materialized) form of actions and the form of external speech

Material and *materialized* forms of actions are the initial ones. At that stage the object of action is conveyed to students either in the form of real objects (the material form) or else in the form of models, diagrams, sketches (materialized form). In both cases actions are carried out as actions producing real transformations. In the case of a primary school the material form of actions may be conveyed in terms of the size of an object or the number of objects. An example of materialized actions is the action of counting representations of objects and diagrams (for example, a child may be engaged in learning to count circles or sticks drawn in a textbook with the help of his finger). The material and materialized forms of action make it possible for students to identify the contents of action— its component operations, the sequence in which they are executed, etc., as well as to control the execution of each component operation.

Perceptual actions refer to an ability to see and hear. An example is the visual counting of objects. While the objects of these actions are external material objects or models and diagrams (materialized objects) they do not experience any transformation as a result of perceptive operations: the latter are theoretical actions. The perceptive form of actions results from transformations of material or materialized actions (38).

The action in the form of *external speech* is characterized by the fact that its object is presented in the form of such speech, whether oral or written, and the process of transformation of that object also occurs in the form of external speech, namely, in the form of oral discussions or else by recording their course.[1] In such a form actions become theoretical ideal but not yet inaccessible to external objective observations.

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[1] Galperin refers to that form as the voiced verbal form (*Ibid.*, p. 10). In view of the findings of subsequent studies, however (see, for example, 18), in which written material was successfully employed, which is, like oral speech, a type of external speech, we believe that these two forms should be combined and called external speech forms. The voiced verbal form is one of two types of actions in the form of external speech. In the works of Galperin the recording of elements of actions in written words is viewed as a method for their materialization (see, for example, 38; 41; and others). In our own view it represents a specific type of actions in the form of external speech, although we do agree that in that form objectifi-

Mental forms of actions refer to cases in which actions are carried out within one's mind and their structural elements are ideas, concepts, and mental operations. The possibility of carrying out an action entirely in a mental form indicates that the action has completed the full course of internalization, and that it has transformed from an external action into an internal one.

Either all structural elements of an action, or else only some of them may be represented in each of these forms. Consider, for example, the case in which a person multiplies two numbers in his mind. In that case the entire action is effected in a mental form. This is the "pure" form of actions. If, on the other hand, the person is working at a lathe, for example, then the executive part will be external, material, orienting operations may be perceptual in form, or else in the form of external speech, or else still in a mental form, while the object of the action is external, material. The action will then no longer be "pure" in form. Its form is determined by that one in which the object, experiencing the action, is represented, and especially the operations that transform the object.[1] For example, in our case the object of the action is represented in a material form, while executive operations are real transformations, and hence the form of the action itself is material. If, on the other hand, executive operations are carried out visually (through the eyes) rather than by hand, we will call the action perceptual. Both material and perceptual operations can be carried out only if material or else materialized objects of actions exist. They may not be combined with other forms of objects. Similarly, we will consider an action

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cation—the external representation of actions—is more clearly expressed than in the form of verbal speech. We base our view on the fact that written speech, too, is speech.

[1] Galperin assumes that "so long as remaining operations require even negligible material supports, actions are held up at the material (or else materialized) level" (36, p. 452). If we accept that criterion, however, we will not be able to distinguish between the material (materialized) form of an action and the perceptual form, since material supports exist in both cases. These cases differ, however, in the form in which operations are carried out: in the first case these are operations of the hand that carry out real transformations, while in the second case these are ideal operations of the eye.

to be an external verbal one when executive operations possess an external verbal (spoken or written) form.

An action's degree of generalization characterizes the extent to which those properties of the object that are essential for carrying out a given action are distinguished from others that are non-essential.

An action's comprehensiveness indicates whether all operations that are originally included into an action are in fact carried out. As an action develops the number of operations that are carried out is reduced and the action becomes condensed.

The extent to which action has been mastered includes such characteristics of actions as the ease with which they are carried out, the extent to which they are automated, and the rate with which they are performed. Initially, each operation within action is consciously distinguished and carried out slowly, but gradually the action is automated and the rate of execution is increased.

These characteristics of action are called independent: none of them follow from others. This means that as action develops, specific conditions are required for the emergence of each of them.

That group of characteristics may also be called the group of primary characteristics. In addition, actions posses a large number of secondary properties tha tdepend on the primary ones and follow from them. These include the *reasonableness* of actions, the *conscious character of actions*, and certain others.

The *reasonableness of action* is determined by the importance of the conditions on which the acting person orients himself. It is determined, first, by the content of the orienting basis of action: this must include significant conditions. Second, it is determined by the extent to which the action is generalized: the greater the measure of generalization, the more it is reasonable. The reasonableness of actions depends on the comprehensiveness of their initial forms: as the action presented to the learner is more comprehensive it becomes easier to assimilate its logic.

The conscious character of actions means not only the possibility of an action being carried out correctly but that it may also be justified in verbal form in terms of its appropriateness: the person performing the action may also be aware of what he is doing and why (39, p. 16).

The degree to which action is consciously executed depends on the comprehensiveness of its representing in an external verbal form and on the quality of the process through which that form of action is assimilated.

While Galperin usually considers only these two secondary characteristics of actions it is possible to add several others, including the degree of their abstractness and their resilience.

The abstractness of action refers to the possibility of executing it in generalized form without support from the relevant objects' sensory contents. It is evident that this property results from a change in the action's form, namely, from bringing all its structural elements to the mental stage. In such a case the objects of actions, the content of their orienting basis as well as apparently their outcome (objective) must be represented in terms of concepts. In addition, action must be generalized, i.e., must be processed along the parameter of generalization.

The resilience of actions refers to the possibility of executing them sometime after their development. It results from their generalization and automation.

Let us consider these major characteristics of actions more closely.

1. The Forms of Actions

The initial form of action may be either *material* or else *materialized*. The difference between these two forms does not concern their operational aspect: in both cases operations are carried out manually and are material in form. It concerns primarily the nature of the object to which actions relate. In the case of materialized forms, the relevant objects of actions are surrogates and models of the original objects. Of course they may replace real objects only when they contain those of the aspects that are the objects of assimilation. Leontiev distinguished between objects in a more general sense and objects of action. Objects of action are those aspects of an object, that aggregate of properties, towards which action is directed (84).

Accordingly, any substitute for the object itself must either contain the object of action within itself or else simply be that object. A second requirement is that the object of action must be represented in a visually perceivable form. In the case of drawings and sketches this requirement is met by the fact that they are methods for representing objects that are visually perceivable. The situation is somewhat more complex in the case of models, for the concept a "model" possesses a number of meanings.[1] V. A. Shtoff (186) defines that concept as follows: a model is a thing that is similar to another thing in some respect. It is in that sense that we ourselves use the term "model". Shtoff writes that a model is always some concrete construction that lends itself to some measure of visualization, is finite, and lends itself to examination or else practical actions. A model represents an object in a simplified, abstracted form. The extent to which a model may be visually perceivable may differ. In some cases those of its elements that lend themselves to sensory perception make it possible to construct a sensory image of the object being modelled. Such models are needed in cases in which these elements themselves, that is those of their properties that are conveyed in sensory form, constitute the object to be assimilated. But it is also possible to employ models whose elements possess no similarity to the elements of the object being modelled; only relations among these elements must be represented in a visually perceivable form. Such models are employed in cases in which it is not the elements from which the object is constructed that constitute the object of assimilation, but rather relations among them (for example, spatial relations).

Accordingly, when we refer to the visually perceivable property of objects we have in mind not the object as a whole, but those of its aspects and properties that are to be studied, i.e., *the object* of assimilation. This makes it possible to employ several types of models: a) models that are geometrically analogous to the objects being modelled (molds, spatial models of molecules, crystals, etc.); b) models that reproduce the dynamics of processes being studied rather than geometric, spatial relations, as well as different relationships, linkages and structures (such models are characterized by a *physical* similarity to the object being modelled and by an identity of the principles that govern their behaviour); and c) models that do not possess either physical or geometrical similarities with corresponding objects. In such cases relations of either structural or functional similarity exist between such models and the corresponding real objects. The selection of a particular type of model is determined by the instruction goal, namely, by what is identified within the real object as the direct object of assimilation. Models that are employed in order to materialize actions must be isomorphic to the object being modelled, i.e., a mutual one-to-one correspondence must exist between the model and the corresponding real object with regard to those properties that constitute the object of assimilation.

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[1] In the literature of modelling, sketches and figures as well are viewed as models. See, for example, B. A. Glinsky's book (52) and others.

It should also be noted that in the assimilation of materialized forms of actions models may replace not only the objects of action but also objects that enter into the content of the action's reference pattern (orienting basis). In such cases models frequently serve as generalized patterns of that aspect of the object which is to be assimilated and that must be identified within the real objects being subjected to analysis. In other words, the model includes the object of assimilation within itself. For example, in a study by L. I. Aidarova (2), a spatial-graphic model that is isomorphic to the morphological structure of individual words is employed as a reference pattern for assimilating the morphological structure of words and the functions that each part of the word may perform. This is an elongated rectangle divided into as many smaller rectangles as there are morphological units in the word. In analysing the proposed word, the student "superimposes" this reference model on the word and identifies existing structural elements. In the above-mentioned study the model was presented in the form of a figure, it may also be constructed in such a way that the corresponding operations may be carried out manually.

In analyzing an action's initial form it is important to establish the relative effectiveness of the material and materialized forms, and within the latter, the effectiveness of various types of materialization. Second, it is important to establish which structural elements within the action should be materialized first.

The theory under consideration is not yet able to provide comprehensive answers to these questions: these problems are still being studied. As an example, however, we will consider a study that we carried out together with V. V. Nikolayeva (172). The experimental material related to elementary geometric concepts and two initial forms of actions were compared, namely, a) actions all of whose major links are material; and b) actions that are materialized and whose type and extent of materialization differed in the first and second group. The experiment involved thirty average fifth-grade students who had not yet studied geometry (ten persons in each of the three groups).

In the first group, real objects were employed as objects of action (tables, books, etc.) and a reference set of attributes was also identified with the help of real objects (for example, the edge of a book represented a straight line). In the second group, geometric models were employed as objects of action and reference patterns. For example, the edge of a ruler was employed as a reference pattern for a straight line, and a model of a right angle was employed as a reference pattern for a right angle. The matching of objects with reference patterns was carried out in both groups by placing the appropriate reference pattern on the object. In the third group, geometrical sketches were employed as objects of action and reference patterns. Comparisons of objects of action with reference patterns could be effected only visually. In all three groups in describing the action the person leading the experiments specified the necessary sufficient attributes for the corresponding concept, pointed to their presence in the reference pattern, and demonstrated the method for employing them in associating objects with the corresponding concepts.

In developing the initial form of the action, assignments given to each group were similar in content and in difficulty. Subsequent forms of action were identical for all groups: all students performed the same tasks in the same forms.

The following concepts were considered: straight line, angle, perpendicular, adjacent angles. Following a series of introductory learning sessions students from all groups were given identical check tests. This called for naming objects containing familiar configurations, to show familiar configurations in objects presented by the experimenter, to represent a figure in different spatial positions, and to find familiar figures within other figures. In addition, it was proposed to solve without assistance several problems calling for an application of the concepts that were developed.

No sharp differences were found to exist among the groups. In all groups the overwhelming majority of tasks were carried out correctly (see Table 1).

Table 1

Group number	Number of problems	Number of correct solutions to problems (per cent)	Number of incorrect solutions (per cent)
I	630	94.3	5.7
II	630	92.7	7.3
III	630	86.5	13.5

We see that learning was most effective in the group in which students were shown real objects (Group I), while students who were shown only drawings (Group III) experienced most difficulties. More than half of the errors, moreover, occurred in assimilating the initial (materialized) forms of actions. Since both the objects of action and the reference patterns were provided in the form of drawings, students were able to effect comparisons only visually, and there was no actual placing of reference pattern on the object. In a number of cases students in the group manipulated the card containing the reference pattern in such a way as to match it with the spatial position of the drawing representing the object of action and sought to identify the desired configuration with their finger. This indicates that it is the *operational* part that plays the role of a leading link and that this is the part that should always be represented in a material form (be subjected to manipulation). But this, in turn, imposes specific requirements in relation to the reference pattern and the object of action: at least one of them must be represented in a form that lends itself to manipulation. This requirement was met in the first two groups, but not in the third.

All students carried out the tasks that were specified in the series of check tests. Each was asked to identify the objects corresponding to specific concepts and to relate objects and images selected by the experimenter to corresponding concepts. But students from Group III ("drawings") were less successful than those in the other groups: the number of objects that they identified was smaller and they were slower in identifying familiar figures from among those that were shown to them.

Members of that group were also less successful in all other respects, and the nature of their errors showed that they were not fully aware of the nature of the essential attributes of the concepts being considered and of the differences among them.

Thus, this study has shown that the materialization of the structural elements of actions must be carried out in such a way as to make possible a material execution of operations. As for the selection of the type of materialization, this was not a significant problem in the present case.

This view is also confirmed by the findings of another study (165) in which types of materialization (sketches, models) were varied in specifying the orienting basis of action. This influenced neither the formation of concepts nor the final outcome.

Nor did shifts from a material to a materialized form of presenting objects produce any substantial difference. There was, however, one important change: the group working with real objects was approximately 20 per cent less successful in carrying out the check tests, which called for the representation of geometric figures in various spatial positions. These were not sketches of geometric figures, but drawings of real objects.

This may be explained as follows: those students who were working exclusively with real objects and did not possess reference patterns in which the objects were presented in abstract forms were unable to distinguish between the reference patterns and other properties of the object. The object itself thus remained merged, in effect, with these properties. The instruction goal merely called for establishing the presence (or absence) of essential object attributes, but not for abstracting them from the properties of the object and representing them in a "streamlined" form. That is a distinct problem whose solution is more or less difficult, depending on the initial forms of action. It would appear that the process of distinguishing desired objects within concrete real objects is facilitated by the use of reference patterns in which the separation of objects from many other properties may be studied.

That an ability to abstract particular properties of objects does not always develop spontaneously is also indicated by findings of other experimental researchers showing that problems are solved more easily when they relate to abstract rather than to real objects. For example, V. L. Yaroshchuk (196) has shown that problems in arithmetic possessing an abstract content are solved more easily than applied problems. Similar findings were obtained by R. G. Natadze (106), E. A. Fleshner (179) and P. M. Yakobson (194).

In this connection it is important to note that earlier experimental studies on the basis of the theory under consideration did not provide for a complete materialization of actions (164; 50). First, in developing geometric concepts the problems were presented in written form and were accompanied by sketches. But these sketches did not always correspond to the conditions described in the problem. As a result, the students found it necessary to apply attributes not to the sketch but to the written conditions. In short, the object of actions appeared in the form of written speech. Second, the attributes were written on cards. But cards make it possible to materialize only the sequence in which attributes are applied. The attributes themselves are provided in an external form that is neither material nor materialized but verbal. While written texts make it possible to objectify the content of attributes more fully than spoken words, they remain verbal as E. N. Kabanova-Meller (72) correctly observes. In situations in which both objects and reference patterns assume such a form material forms of operations are not possible. Finally, these studies did not provide for a materialization of either the logical rules for associating objects with concepts or of instructions relating to the sequence and content of the operations to be carried out. Both are included in the content of the orienting basis of the action of associating objects with concepts.

It does not follow, however, that attributes need not be recorded on cards when they are presented in the form of models. In the study mentioned earlier (172) students in each of the three groups were further divided into two sub groups, one of which was given cards with lists of attributes that were essential for the given action (sub-group A) while the other (B) was not.

It was found that within all groups the results of sub-group A were somewhat better than those of sub group B. This was especially pronounced in the case of the third group ("drawings"). In the course of the learning process sub-group A made only one half as many errors as sub-group B (29, as opposed to 56). This is because models of attributes that are not supplemented by verbal forms of representation do not produce the required effect. In the case of B sub groups, the experimenter initially found it necessary to remind students of relevant object attributes and of the order in which they should be applied, i.e., to supplement the model with oral, verbal representations. The differences between these sub-groups thus actually show the relative effectiveness of the written and oral form of verbal supplements to materialized reference patterns of attributes.

It should be noted that the role of speech is not limited to reference patterns. The verbal form must accompany the entire process through which actions are carried out in their initial form. Material (materialized) and verbal forms of action proceed in parallel, as it were. In the material (materialized) form the speech form is developed simultaneously. Only then is it possible to shift to verbal forms of action and to gradually emancipate actions from materialization.

The external speech form is the second one in the process of an internalization of actions and their transformation into mental form.

In the early stages of development of the present theory only the voiced form of action was considered. More recently, as studies have moved beyond the stage of laboratory experiments, the written version of speech has been employed. This is especially true of the studies of M. B. Volovich (18) of the development of elementary geometric concepts and actions. That experiment demonstrated that the organization of external verbal actions in written form makes it possible to produce well-developed concepts and well-developed mental actions. But there are still no data for a comparative analysis of these two types of external verbal forms of action and for identifying the specific course of each.

The written form can, of course, be employed only after a person has mastered the corresponding written language. Accordingly, in the case of preschool-age children and of children from primary grades the form employed is usually the spoken form. In that form "speech becomes a carrier of the entire process, that is, of both the problem and of the corresponding action" (36, p. 454).

Speech actions are reflections of material or else materialized actions. Their object-related contents remain the same (for example, addition with the help of sticks and verbal count), while their form experiences a qualitative change.

Galperin observes that in assimilating this new form of action the student must orient himself both on its object-related contents and on the corresponding verbal expression. Should the integral unity of these two aspects of verbal action be violated, the action will be defective. An orientation on the verbal form alone produces formalism in the assimilation of knowledge and of skills. If, on the other hand, the student is guided only by an object-related content that is not reflected verbally, he will be able to solve only that set of practical problems for which orientation at the level of perception is sufficient. In such cases, an ability to reason and to give substantiation to the conceptual basis of obtained solutions will not develop (*Ibid.*, p. 455).

Formalism of verbal actions usually occurs in cases in which the verbal form is introduced without the material one (or materialized one). Formalism may also occur in cases in which the verbal form is not produced by an assimilation of the material (materialized) forms, but immediately replaces it. Finally, in cases in which the material (materialized) form of action is assimilated separately from the verbal form and is not replaced by the latter in time, an automation occurs of the actually insufficiently comprehensive material (materialized) form, which then becomes habitual and tends to limit the activities of students to the sphere of practical problems.

The development of a comprehensive verbal form of action presupposes a definite level of generalization of its material form. In particular, this means "that traits and properties that are essential for the action and represent its specific object are distinguished within the concrete contents of real objects" (*Ibid.*, p. 456). It is only then that a transformation of actions into a verbal form is possible: the properties that have been selected are consolidated in words and become their meaning. At that point a separation of these properties from objects becomes possible, as does their use as abstractions and as comprehensively developed verbal objects. Entire actions follow a similar course. "It is only because words possess a material foundation and in this sense are material things (not *merely* material, but *also material*) that students may exert actions upon them (and through them upon their meaning) just as in the case of any material object" (*Ibid.*). Finally, it is important to emphasize that a shift of actions to the verbal form refers not to an *ability, to describe*, but rather to an *ability to carry out* actions in verbal form. In learning how to multiply, a child must verbally carry out operations of multiplication, i.e., solve the corresponding problem by carrying out the action being developed in verbal form, rather than describe how one multiplies two numbers.

The *mental form of action* is the concluding one in the transformation of actions from external to internal ones. A clarification of that form of action may be appropriate, since the content of that concept is not always correctly understood. In particular, there are references in the literature to the incompatibility of the following aspects of mental actions: a) the psychic reflection of external material actions, b) actions directed at images of external objects and of external phenomena, c) an ability to carry out specific object-related actions in one's mind (151). Actually, all these aspects of mental actions are fully compatible with each other. The first emphasizes the point that in terms of their origins, mental actions are associated with material actions and constitute their reflection. And that means that mental actions include all those traits that were included in the material action but have now all become ideal. Instead of real things the corresponding objects of actions are now their images, and real transformations have been replaced by ideal ones. In other words, we are now concerned with actions directed at images, as noted in the second proposition. Having become mental, actions do not lose their object-relatedness; but while earlier, the person in question carried out practical actions in transforming external objects, he now carries out actions in his mind that transform the images corresponding to the objects. As we see the conception of a mental action as one in which the objects are images of real objects and phenomena from the external world, while the corresponding operations are carried out in one's mind, fully describes the specific characteristics of mental actions.

Certain critics take the position that "it is more correct to consider mental actions as any action that is associated with the solution of any problem, and the corresponding selection of methods of action, hypotheses, conclusions, etc." (*Ibid.*, p. 158). It is not possible to agree with such a view. For, let us assume, for example, that our problem is to place furniture in a room. Any reasonable person will presumably first consider how this may be done, in what order the furniture should be moved, etc., i.e., identify a method of action and a plan. It does not follow, however, that the furniture will subsequently find itself in a particular position as a result of that mental action alone. That operation will be practical, but like any practical action, it will have an orienting part that contributes to the executive part of the solution to the problem, which in this case is purely practical.

Other authors interpret the mental actions in the theory being considered as "an ability to carry out various operations in an automated manner" (101, p. 160). This, too, is not the case. Automation is a distinct characteristic of actions that may relate to any form of action: material, verbal, or mental, and actions may be mental without being automated (50; 36; and others). By no means all mental actions are performed in an automated manner, even though any mental action that is repeated many times may become automated.

The transformation of external verbal actions into mental ones proceeds through a transformation of audible speech into a corresponding auditory image. Galperin observes that "within the mind the auditory form of speech becomes a representation, an auditory image of the word" (36, p. 457). Initially that new form of action possesses a clearly expressed articulation basis, and Galperin refers to this as an "external silent speech". This is already an internal action but it is still externally-oriented, as it were, towards another person (to oneself as to another person). Very quickly, however, that form of action experiences a transition to a mental action proper. Such actions are then performed in the form of internal speech and become individualized in the proper sense of that term, namely, they are executed within a person's mind for his own self without being addressed to another person. Its object-related content, however, continues to be the same as in the initial form, and its social character, too, is therefore retained.

2. The Generalized Nature of Actions

Both in our own country and in other countries the literature on psychology contains many studies of the problem of generalizing existing knowledge and abilities. They generally emphasize an analysis of the particular properties in relation to which generalization occurs—their physical nature, importance and relevance to the solution of problems (15; 182; 251; 202; 286; and others). Distinct stages of generalization have been identified in ontogenesis

(24; 182; 148). Many such studies consider the role of specific factors in the process of generalization: of words (136; 93; 180); and also of variations in nonessential attributes (66; 102).

Bruner, Goodnow, and Austin have identified a number of factors that influence activities leading to generalizations, including specific ways in which the learner understands the problem that is formulated, the nature of the examples that are employed in the process of generalization, the anticipated consequences of actions that are performed, the nature of the constraints that are placed on particular activities, and the nature of the method that is applied to evaluating such actions (210).

Rubinstein showed the importance of such operations as analysis, abstraction and synthesis (144). In his own studies, in fact, the concept of generalization is viewed as a fundamental thought process. The views that the psyche is an activity, however, calls for a more precise definition of "generalization" as "a basic thought process" and for an identification of its position within a system of activities. Within the theory of the stage-by-stage development of mental actions generalizations are viewed as one of the basic *characteristics* of any action. They are not limited, accordingly, to the sphere of thinking.

In order to develop cognitive actions possessing a specified measure of generalization it is important to know the psychological mechanism on which generalizations rest, that is, the dependence of generalizations on an action's structural and functional components. In this connection, the studies of Zaporozhets and his associates A. G. Ruzskaya and N. N. Poddyakov showed that the process of generalization is influenced by the orienting actions that are directed at the objects being generalized (63; 121; and others).

Similarly, studies that we carried out jointly with Konstantinova, Teplenkaya, Barayeva, Kochurova and Lopez showed that the generalization of actions and of the objects towards which actions are directed proceeds exclusively along those properties that enter into their orienting basis. Of course, generalization can proceed only in relation to properties that are inherent in all objects of the given class. But the presence of common properties within a set of objects does not automatically produce a generalization in terms of these particular properties. The process of generalization itself is not directly dependent on the general properties of the corresponding objects. In particular, in studying the manner in which geometric problems are solved by the sixth- and seventh-grade students we found that they did not make use of complete descriptions of such concepts as adjacent angles and vertical angles and that they neglected essential attributes (present in all objects related to the corresponding concept). In defining adjacent angles, for example, the attribute "possessing a common side" was neglected, even though it was perceived that all adjacent angles that were considered possessed a common side and it was also represented when students were asked to draw adjacent angles. Yet this aspect was not reflected in the contents of the corresponding concept and was neglected in the generalization of the corresponding objects (162).

Similar results were found in our joint studies with Konstantinova (165) of such elementary geometric concepts as straight lines, angles, and perpendicular lines. The test was applied to twenty-five fifth-grade students who had not yet studied geometry and whose grades in other subjects were very low or low.

The following was a specific feature of the corresponding teaching process: all figures were represented in identical spatial positions. In this way a nonessential attribute, namely, position in space, accompanied the essential attributes of all figures. The teaching process was organized in such a way that students were immediately oriented on the system of essential attributes.

In a series of check tests the students were shown objects relating to the concepts being considered but presented in a variety of spatial positions. In addition, figures that were superficially similar to the initial objects were shown in a similar spatial position but they did not relate to the concepts being considered (for example, slightly inclined yet almost perpendicular lines). The students were also asked to draw several different objects illustrating the concepts being considered.

All students responded to the check tests correctly. Each one of 24 students answered six questions. Of 144 questions concerning the recognition of a straight line 139 were answered correctly. There were no errors in recognizing angles and perpendicular lines. And the second type of problem was also answered correctly: each student drew at least three figures in different spatial positions.

In short, in a case in which an orientation on a system of essential attributes was initially provided, nonessential object attributes did not enter into the corresponding generalizations even though they were present in all the objects that were considered by the students. This was particularly evident in a joint study with J. Lopez (92) in which the experimental data related to geometrical figures similar to those employed by Vygotsky and Sakharov. The essential attributes (to be recognized) were the length of a figure's base and its height. As in all studies of Vygotsky and Sakharov the figures were divided into four classes, depending on their dimensions. More specifically into "bat" (low figures with a small base), "dek" (high figures with a small base), "rots" (low figures with a large base), and "mup" (high figures with a large base).

Colours and shapes were chosen as nonessential properties that were common to all objects of the given class. This is because studies in child psychology have shown that these are precisely the attributes that are most significant for preschool-age children. The tests were applied to 100 Cuban children between the ages of 6 years and 6 years and 9 months.[1] Five series of experiments involving 20 children each were carried out.

In the first series of experiments objects taken from each of four classes were always coloured in the same way: "bat" figures (low figures with a small base) were always red while "dek" (high figures with a small base) were always blue, etc., their variable attribute was their shape. The reverse was true in the second series of experiments, in which each class of objects possessed a constant form, while colours varied. In a third series of experiments the figures of each class possessed both similar forms and similar colours. Thus, in these tests it was either colour or form, or both colour and form that could serve objectively as joint recognition attributes. It was possible to associate a figure with a specific class by relying on both. But these attributes were not included in the orienting basis of the recognition actions. In the fourth series of experiments each class of figures possessed its own colour, but all figures of all four classes were of the same shape (cylinders). Conversely, in the fifth series each class of objects possessed its own form but objects of all classes were of the same colour (red). Thus in the last two series of experiments the figures possessed common nonessential attributes, that could, however, objectively serve as a basis for recognition (colour in the fourth series and form in the fifth) as well as an attribute that could not serve as a basis for recognition (form in the fourth series and colour in the fifth), since they were common for figures of all classes.[1] From the very first essential attributes were introduced into the contents of the orienting basis of recognition actions. In carrying out the action in its material form students relied on standards (rulers) that they were given to establish the lengths of the bases and heights of the figures. Then they relied on the logical operation of associating objects with concepts in determining whether the given figure did correspond to a given class of objects. They were also given instructions concerning the nature of the operations to be carried out and their sequence.

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[1] They were school-age children by Cuban standards since schooling there begins at the age of six years.

In carrying out the material form of the action additional assistance was provided to one half of the students in each group (sub-group A) that facilitated the identification of common colours (forms) in the figures: in particular, those figures that had been recognized were not removed but remained within the students field of perception. That assistance was not given to students in sub-group B of each group: the figures that had been recognized were removed, so that students perceived only that figure with which they were currently working.

Following the learning process students in all series were given the same set of check tests. These emphasized the recognition of: a) new figures some of whose nonessential attributes, which until then had been common and constant for objects of the given class, were varied: either new colours or forms were now added, or else colours or forms that had until then been associated with other classes; and b) figures that possessed the same colour (form) as figures of another class in the teaching experiment but did not possess the essential attributes associated with the given concept. These problems were given in one of two forms: either a direct presentation of new figures or else verbal descriptions by the experimenter. In addition, students were asked to classify objects and to give descriptions of figures of a given class.

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[1] The development of concepts followed the methodology employed in Teplenkaya's study (176).

The results of that study have shown that 42 per cent of the students were aware of the presence of a constant colour (or form) in the objects that they were shown, and that most of them had already established this in the process of forming the first concept. In only 65 cases out of 7,420, however (this represents 0.9 per cent), students had recognized objects on the basis of these attributes. And even in those cases they viewed these attributes merely as elements of recognition that indicated that the object also possesses other attributes, such as a particular magnitude for its base and for its height.

All groups and sub-groups passed through a series of check tests successfully. Individual errors (2.6 per cent in recognizing figures that were directly perceived and 5 per cent in the case of recognitions based on descriptions) resulted from an incorrect recognition of essential properties (imprecision in measurement, an incomplete analysis of descriptions, etc.) rather than from an orientation on non-essential attributes. Only 3 children out of 100 made errors associated with an orientation on colour or form. These errors represent 5-10 per cent of the total number of problems that were answered.

Most children answered the questions quickly and without vacillating.

The basis of generalization is not thus now only what is common in a class of objects. This is a necessary, but not yet a sufficient condition. *Rather the basis of generalization refers to those properties of objects that have been included into the orienting basis of those actions that are directed at analyzing the object.*

Accordingly, a control of the generalization of cognitive actions and of the knowledge that they convey concerns the formation of these actions through appropriate adaptations of the contents of their orienting basis, rather than identifying the common properties of objects.

This principle also explains the typical flaws in attempts to generalize knowledge that are encountered in practice.

Let us consider again the case in which at the visual level students perceive the common side of all adjacent angles and are also reminded of its relevance, yet fail to include it in a generalization. This can be explained by the following. While the attribute "common side" was remembered, it did not operate as an orienting element with regard to the problems that they confronted. Our survey of these problems relating to "adjacent angles" has shown that in fact problem specifications related to supplementary angles, i.e., angles with a common side. Accordingly, students merely had to establish the presence of only one attribute, namely, whether the sum of the angles was 180°. Only this attribute was included into their orienting basis of action. For many students the contents of the concept "adjacent angles" came to be limited to that single attribute ("two angles whose sum is 180°"). Because the presence of "a common side" had not been included in the orienting basis of action it did not occur within the resulting generalization either.

A simple explanation is also provided for the frequent cases in which generalizations relate to nonessential common attributes. Since at best school students are given a set of orienting attributes (through definitions), while an orientation of activities on these attributes is not provided, these attributes may not enter into the orienting basis of action. The orienting basis is then developed by the students themselves, and once again generalizations are then effected in relation to nonessential attributes rather than to the attributes specified in definitions.

Conversely, as soon as a system of necessary and sufficient attributes is in fact included into the orienting basis of action and a systematic orientation on these particular attributes begins to operate in carrying out all suggested assignments, generalizations proceed along that particular set of properties, and other common properties exert no influence whatever on the resulting generalizations. With regard to the findings mentioned earlier, this means that it is not necessary to vary nonessential properties or attributes in order to arrive at generalizations in terms of essential attributes. It is sufficient to include the corresponding set of essential properties into the orienting basis. It follows that generalizing processes are not guided directly by objects of action, but are mediated by the subject's activities and by the elements included in their orienting basis.

This principle also explains the manner in which properties that are essential came to be differentiated from those that are merely common: only those properties that have been included into a person's orienting basis of action are perceived as essential.

It has also been shown that the view that colours and forms play the major role in the generalizing capacities of children holds true only for unstructured situations. In situations in which generalizing activities are controlled they relate from the very beginning to systems of attributes that may not be visually apparent. In such cases the presence of common visually apparent properties exerts no perceptible influence on the course and contents of generalizations.

These findings fully agree with findings of other researchers concerning preschool-age children and schoolchildren in primary grades (1; 57; 58; 187). These findings make it necessary to revise existing conceptions concerning the learning capacities of children. When generalizing processes occur in an unorganized or insignificantly organized manner generalizations tend to occur on the basis of materials that are presented (39), or else of empirical perceptions (58). In those cases, however, in which that process is controlled, young children may arrive at comprehensive generalizations reflecting relevant properties (38), or else at theoretical generalizations (58).

Control of generalizing processes requires a knowledge of their basic qualitative states. These have not yet been identified, even though it is known that the material (materialized) form of generalization differs substantially from its verbal form. In the first case object properties identified as a result of the abstraction process are employed only when these objects are present. In all subsequent forms of action, such as verbal action, essential properties are separated from external objects and are transformed into distinct objects, as it were (36, p. 456). Thus, while forms of action are not causally linked to generalizing activities both influence each other and affect transitions to the next genetic stage.

3. The Extensive Form of Actions and Their Assimilation

That mental operations may become "condensed" in the course of their development has long been known. This was first noted in logic rather than in psychology, for logic has long considered abbreviated chains of reasoning known as enthymemes. Enthymemes are external phenomena in logic. Indeed, from the point of view of logic there may be two such variants: a) a conclusion may be reached without considering the major premise, but then it is not logically consistent since it does not meet the specifications of the law of sufficient justification; b) a major premise is taken into consideration, but is not expressed in an extended external or internal verbal form; in such cases there is no difference between an enthymeme and a common complete deductive inference, since the nature of the verbal form in which a major premise is presented in reasoning is not relevant to logic—so long as it is presented in some form.

Accordingly, an enthymeme is a psychological rather than a logical fact. It concerns the appearance of a part of knowledge and part of mental operations in a new form of existence at a certain stage of development of mental activity: they are "taken into account" and considered in the process of reasoning, but are not actualized and do not become an object of awareness.

P. A. Shevarev (183) was first to describe these psychological facts in some detail in connection with a systematic study of condensation processes in mental activities for different object data (185). The studies that were carried out under his guidance showed that such process did take place in the development of practically any mental activity or ability. It was also established that a "disengagement" of individual links from mental activities occurred in the final rather than the initial stages of their development (184).

In particular, a study of solutions to geometric problems indicated that the number of complete chains of inference declines as one shifts from lower-grade students to upper-grade students. Sixth-grade students relied on full chains of inference thirteen times more frequently than adults, while poorer students in the same grade relied on such chains nearly three times more often than the better students (166).

The nature and logic of condensation (reduction) processes are of considerable interest: what are the links in reasoning activities that are first to be abandoned, and which are the ones that continue to be ever present in one's mind. At the present time this is still not fully understood, even though corresponding studies have produced some information. In particular, those of N. K. Indik (68) and A. N. Sokolov (159) showed that those elements of mental activities that played an orienting role were first to be abandoned, while operational (executive) elements underwent condensation at a later stage.

Our own study (166) showed that at first an awareness of corresponding orienting operations continued to exist in relation to both executive operations and control operations, but was later retained only in relation to control operations and then vanished altogether.

But the failure of certain elements of mental activity to be actualized does not necessarily imply that condensation has taken place and that it may be replaced if needed by a form in which full awareness exists. It may simply indicate that the corresponding reasoning process is faulty. In this connection Sokolov (159) notes that in his studies of the process of solving physical problems failures to engage in substantiating reasoning were frequently due to a lack of understanding rather than to a process of reduction.

This was evident in our own analysis of the process of solving geometric problems as well (166). In cases in which normal reductions of mental activity take place non-actualized elements retain a capacity for restoration and students are able to reconstruct the full chain of substantiating reasoning when asked to justify their actions. In cases in which a failure to actualize individual links of mental activity was attributable to other causes, students were either unable to re-establish anything or else produced propositions that could not have served as a substantiating basis.

Awareness is precisely the retention within a student's consciousness of the objective logic of a condensed activity and the possibility of reproducing the elements that were eliminated. It exists when an action is initially developed in terms of the full range of the corresponding operations and when these operations are objects of special assimilation, i.e., actions. In cases in which actions are developed through practical adaptations, however, without an awareness of component operations it is not possible to transform them into actually conscious actions (84).

Such an understanding of the process of condensation – not as one in which elements of mental activity are lost forever, but as a process in which they experience a transition into a special form of existence—explains the ineffectiveness of attempts to develop actions directly in a condensed form. In such cases the action's logic is not unfolded and the subject does not become conscious of it. It exists for him neither at the level of actual awareness nor at the level of those things of which he is currently unaware.

It has been found that a condensation of cognitive actions may occur in relation to memory as well as to thought. In particular, G. Miller and his colleagues show that in memorizing senseless words inexperienced students construct complex hierarchical linkages, while experienced ones proceed in more "direct" ways (272). Similar facts were described earlier by A. A. Smirnov (158).

In a study carried out by N. D. Belov under the guidance of Galperin students were taught to become aware of condensation and to assimilate that principle itself. It was shown that this helped them become aware of other instances of condensation and to apply that principle more widely (7; 36).

This characteristic of the process of condensation of the operational composition of actions indicates that teaching programmes must provide for the assimilation of actions in their extensive form. For genetically reduced actions represent a later state, and above all they function comprehensively only when the person in question is able to reconstruct them in their extended form.

In this connection, Galperin observes that "the psychological mechanism of comprehensively developed actions is not limited to those orienting activities that are explicitly performed. It includes the entire system of earlier forms of the given action, which are no longer carried out explicitly but are kept in mind, and thus provide for a retention of the objective logic of the condensed action within the consciousness of the student, and hence for a conscious execution of that action" (36). Actions "in accordance with a formula" (in short, of the type "five times five is twenty-five") should be the outcome of the transformation of extensive forms of the corresponding action and mark the conclusion of a process rather than its primary objective.

The extent to which an action is *assimilated* is one of its least examined properties. Its principal content concerns the automation of actions: gradually, individuals perform an increasing number of operations without being consciously aware of them. A number of factors suggest that automation is associated with the mechanism of condensation: although operations that are not carried out but only envisaged appear to leave the sphere of current awareness, they continue to exist at an unconscious level.

Like the degree to which an action is condensed or reduced the degree to which it is assimilated is reflected in the rate and ease with which it is performed. While it represents the independent type of change in actions, the degree to which an action is assimilated can nevertheless inhibit changes in the form of actions. Should an action in a material or else a materialized form reach the stage of automated execution, considerable effort will be required to transform it into a verbal form. It follows that the teaching programme must above all provide for transformations in the forms of actions and to bring them to the desired form without any automation of intermediate forms. The assimilation of action in these forms should be retained at the level of conscious execution, and automation should take place only after the action has been assimilated in the given form.

Galperin observes: "... All intermediate forms of action are subject to assimilation only up to a certain point, namely, until they are freely and correctly carried out, that is until they are assimilated without symptoms of automation" (38).

§ 3. Types of an Action's Orienting Basis

It has already been noted that actions include three parts: orienting, executive and control.

Research findings have shown that the orienting component plays a decisive role in the development of actions (126; 48; 62; and others). It determines both the rate at which actions develop and their quality.

The orienting component of action is concerned with: a) correct and rational formulation of the executive part

(119; 127; 155); its contents then relate to an examination of the conditions that the pre-set executive part objectively requires; and b) effecting a rational selection of one of the possible executive actions. That function of the orienting component of actions is clearly evident in the analysis of actions employed in playing chess. For in such cases the main task of the orienting component of action is to produce a correct selection of the next move, while the executive component is concerned with changing a figure's position from one field on the chess-board to another in accordance with corresponding rules. In carrying out the orienting component of such action the player must be guided not only by the set of conditions that produces a correct shift from one field to another (the executive component of action), but also by the particular characteristics of positions in chess that bear on the selection of a next move (175).

In principle, the orienting component thus serves not only to execute the action correctly, but to help select one of many possible executions. And in carrying out the orienting component of action producing these functions persons are guided by the action's orienting basis. Naturally, the effectiveness of the action's orienting component depends, above all, on the contents of the orienting basis; the latter may differ substantially from case to case. Research findings have shown that the effectiveness of the orienting basis does not depend on the form in which it is presented (material, materialized, external verbal, etc.) but does depend substantially on the extent to which the knowledge (guidelines) that it contains is generalized, and on the comprehensiveness with which it reflects the conditions that will objectively determine the effectiveness of actions. Their effectiveness also depends on the way the orienting basis of the action is constructed (34; 36; 38; and others). In terms of its comprehensiveness (sufficiency) the action's orienting basis may be comprehensive, inadequate[1] and redundant. In terms of the extent to which it is generalized the orienting basis of action may be concrete, and then be applicable to a unique, specific case. But it may also exist in a generalized form that reflects the essence of an entire class of specific cases, and may then be applicable to each such case. One may distinguish the following cases relating to the method through which the orienting basis of action is constructed: a) it may be given to the student in a pre-established form; b) it may be developed autonomously by the student. Such an autonomous development may itself take place in two distinct ways: through a "trial-and-error" method in the course of execution; or through a conscious application of a general procedure (method) for developing the orienting basis of action. This, too, may be conveyed in a pre-established form or may be developed autonomously.

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[1] One should not confuse this characteristic with the extent to which the orienting component of action is presented in extensive form: a reduction (condensation) of action may occur both in cases in which it rests on the orienting basis that is objectively adequate and in those in which the orienting basis is objectively inadequate and insufficient.

1. Types of the Orienting Bases of Action

Differences in the extent to which the orienting basis of action is generalized, in its comprehensiveness, and in methods employed for constructing it make it possible to distinguish several types (34; 36; 38; 48).

While four such types have been identified experimentally, in principle, there may be much more (see Table 2).

Table 2

No.	Degree of generalization of orienting basis	Degree of comprehensiveness of orienting basis	Method of acquisition of orienting basis
1	Concrete	Inadequate	Developed autonomously
2	Concrete	Comprehensive	Conveyed in a pre-established form
3	Generalized	Comprehensive	Developed autonomously
4	Generalized	Comprehensive	Conveyed in a pre-established form
5	Generalized	Inadequate	Conveyed in a pre-established form
6	Generalized	Inadequate	Developed autonomously
7	Concrete	Comprehensive	Developed autonomously
8	Concrete	Inadequate	Conveyed in a pre-established form

In principle, as we see, it is possible to envisage eight different types of the orienting bases of action. The first three were first identified experimentally (the fourth was identified somewhat later). We will consider these first.

The first type possesses an incomplete structure. Its guiding elements are of a specific form, and are identified by the subject himself through blind trials. Actions guided by such an orienting basis proceed very slowly, with many errors and are sensitive to even minor changes in conditions of execution.

The second type of the orienting basis is one in which all conditions needed for a correct execution of actions are present. But they are conveyed to the subject in pre-established forms and also in forms that are specific for the given situation. While the corresponding actions develop rapidly and without error, and are also more stable than in the first case, they are transferable only to similar situations.

The third type of the orienting basis possesses all necessary attributes, and its guiding elements have a general form which is characteristic of an entire class of phenomena. When applied to specific cases the orienting basis of action is elaborated by the subject autonomously, with the help of a general method that he is also given. The corresponding actions are not only rapid and error-free but are relatively stable and transferable to a wide range of situations.

With regard to the first and third types it should be added that while in both the guiding elements are identified autonomously these are produced in different ways: in the first case a "trial-and-error" method is employed, while in the third case this is done with the help of a specified method. In principle, it is also possible that the learner may not only identify a system of guiding elements for each specific case through the method explained to him but finds a desired method independently. This would represent an instance of genuine creativity.

Experimental studies that have been carried out for a variety of subjects, including graphic writing habits (119), grammatical concepts (3; 61), training in production methods (127), basic arithmetic (45; 149; 161), chess games (175) have confirmed the high effectiveness of actions developed in the context of the orienting basis of the third type.

Let us consider three such studies. That of Pantina (119) is concerned with the development of writing among children. Children in the group, in which the orienting basis of the first type was used, were shown a reference image of the letter that they were asked to write. Its separate elements were noted and the following type of explanation was provided (in relation to the Russian letter "*u*"): "We begin to write at this point (which is shown), follow the line downwards until that point (which is shown), now we begin to curve at the bottom line towards this point (which is shown), and now we curve upward and move towards this particular corner (it is shown)." The child then initiates autonomous actions, having before him a reference image of the final product, namely, the assigned letter (or else its component). In the course of this action the experimenter points to errors and explains how they should be corrected. In case of need he repeats a second time and shows how the required final product may be obtained. The teaching process is continued until the child produces the letter (or one of its elements) three times without errors. Next another letter is taught in the same way.

As we see, the orienting basis is inadequate: the child is given only some indications concerning the manner in which the action should be carried out. As a result, a correct execution of actions is achieved only after many trials. Thus, 174 repetitions were needed for a correct writing of the first letter. But having learned to write one letter correctly the student was then unable to immediately identify the orienting basis of action that was appropriate to the second: the initial orienting basis of action was specific and applicable only to the first letter. In order to write a new letter correctly the student had to seek the necessary guiding elements once again and this required 163 repetitions.

In the case in which the second type of the orienting basis was employed the teaching of writing took place as follows: here again the child was given a reference image of the letter (product of action) but a system of dots was employed that guided the executive component of the action in arriving at the necessary contour. The child learned to copy these dots and to employ them in writing letters. In that case the child received all necessary guidelines immediately, but they were useful only in arriving at a specific contour. Having learned to place dots in the required positions the child wrote the letter without errors. But in order to write a second letter these dots were no longer relevant, while by himself the child could not identify another system of dots corresponding to the contours of the next letter. The teacher had therefore again to provide the necessary guidelines, while the child had to assimilate still another specific orienting basis.

The learning process proceeded more successfully in that case than in the first one: only 22 repetitions as opposed to 174 were needed to write the first letter, and 17 for the second. This is because the orienting basis was complete yet not easily transferable because of its specific character.

Learning on the orienting basis of the third type proceeded in quite a different manner. Instead of providing a system of guidelines the experimenter explained a principle for identifying them, namely, that the required dots should be placed in those positions within the letter at which a change occurs in the direction of the lines. This was shown to children in a particular letter, and they were then also shown how to apply the principle to several other letters having similar elements.

Thus, in that case the content of the orienting basis is different: it is not a system of specific guidelines but a general principle ("units" of contours) which is applicable to any specific case, since any contour may be divided into a particular number of straight segments. The application of that principle is assimilated with the help of several specific examples. The examples thus serve not as objects of assimilation but as means for assimilating that which is general and which constitutes the essence not only of each of them but of all other specific cases. The students identified systems of reference dots by themselves (constructed the contents of the orienting basis of action) for any letter and rapidly learned to reproduce it correctly. Fourteen repetitions were needed to arrive at a correct representation of the first letter (instead of 174 in the first group) and eight repetitions for the second, while after the 7th letter the students were able to write any letter correctly after only one trial. The students in that group were able to transfer the method that they have assimilated to the reproduction of practically any contour, including letters from the Latin, Arab, and Georgian alphabets, as well as of drawings of objects. In addition, the action that had been assimilated was also applied successfully under new condition, such as writing on one line or without lines (119).

Similar findings were produced by our study of the process of learning elementary chess yields (175).

An analysis of the logic of the game of chess, and in particular of typical mistakes that beginning chess players make, has made it possible to identify a number of conditions that must be taken into consideration at all stages of a chess game: 1) state of material correspondence of one's own forces with those of the opponent, 2) interactions within one's own forces, 3) the occupation of space, 4) the timeliness of operations directed at producing interactions among forces and at occupying space.

Students were taught to solve simple problems in winning against a single king by such combinations as a king and a queen, a king and two rooks, a king and one rook and a king and two bishops. In the case of teaching with the help of the orienting basis of the first type, students were only shown the executive part of the solution together with an image of the final "outcome"—the checkmate position. In the case of teaching with the help of the second type of the orienting basis, the entire system of conditions on which the outcome of the game depends was identified. But this was always done in a form relevant only to the specific situation. For example, it was pointed out that a particular move was preferable to another because it isolated the opponent from specified fields, while making it possible to initiate joint interactions with another figure. In the case of teaching with the help of the orienting basis of the third type all conditions were presented in a generalized form. Students first learned to orient themselves in relation to each of the conditions separately, and then to analyze specific positions autonomously in the light of all relevant conditions.

For all three groups the following information was recorded: whether or not the objective was achieved, the time required, the number and quality of the moves, the number of initial demonstrations provided by the experimenter, and the possibility of transferring the new abilities to other situations. In the case of teaching with the help of the orienting basis of the first type much time was required in meeting the specific objective (to win with a king and a queen).

The instructor found it necessary to show the required move three or four times. The game improved through a gradual memorizing and recall of moves carried out by the instructor. On the average 55 moves were needed, requiring 34 minutes (the problem could be solved in 10 moves). The game's quality was low: after the first demonstration only 25 per cent of the total number of moves were correct. After the last demonstration this rose to 50 per cent. It is characteristic that the students in that group could not explain why they selected a particular move. This indicates that their solutions were mechanistic and that they did not understand the internal logic of a chess game. As a result even minor changes in the conditions defining the problem (such as a different initial position of the same figures) required a second round of teaching. Naturally, there was no ability to transfer new knowledge to different situations (such as to checkmate the opponent's single king with the help of a king and two rooks, a king and two bishops, etc.). Thus, the first type of the orienting basis made it possible for the students to acquire specific types of knowledge that can be applied effectively only to the particular situations in the context of which it was assimilated.

The learning process was much more effective in the case of the second type of the orienting basis: all students in that group were able to solve the problem during a single attempt. Solutions required an average of 12 moves in 6 minutes. The quality of the game was considerably higher: 76 per cent of the total number of moves were correct.

The abilities that were acquired were more independent of the specific situations defined by the given problem: in their very first attempt all students succeeded in solving a problem relating to a new initial position of the figures in question. At the same time the specific nature of the guiding elements served to inhibit the execution of actions in new situations. As the number of similarities with the conditions of the initial problem declined the process of solving new problems became increasingly difficult, the number of trials and errors increased and more time was required. Problems relating to situations that differed substantially from the initial ones (for example, to win against a single king with the help of a king and two bishops) proved to be beyond the students' abilities.

Learning abilities based on the third type of the orienting basis produced far better results than in the first two groups. Members of that group were able to solve the initial problem on the first trial in 3 minutes time, making error-free moves. Changes in the figures' initial position did not produce any deterioration in the game: all members were able to solve the problem rapidly without a single error. They were also able to solve entirely new and much more complex problems (to win against a single king with a king and two bishops and a king and a rook).

Similar results were obtained in the studies of Reshetova and Kaloshina (134). These were concerned with the development of a general method for designing rational technologies for processing work pieces in carrying out "complex" operations.

In the case of usual teaching, procedure technologies (the orienting basis) for producing work pieces are designed by specialized technologists, while workers merely execute the corresponding actions. Naturally workers must be given instructions (an orienting basis) for each new specific assignment, which are conveyed to him in a pre-established form (at best the orienting basis of the second type). The third type of the orienting basis was employed in experimental training. Its possibilities were demonstrated in developing a method for arriving at a rational sequence for processing various planes of individual work pieces.

A preliminary test of the relevant abilities of group members (ninth-grade students) indicated that only seven per cent of them were able to analyze correctly the technological conditions determining the selection of a processing sequence and that none of them were able to indicate the correct processing sequence. They possessed neither the knowledge nor the skills required by the correct processing technology. After learning the method for selecting a rational processing sequence in accordance with the third type of the orienting basis, however, their effectiveness in solving new problems (that were not presented in the training series of the experiment) was reflected in the following figures: in 98.8 per cent of the cases they were able to analyze correctly the conditions that determined the selection of a processing sequence; in 99.6 per cent of the cases they selected the processing sequence correctly, and in 100 per cent of the cases they processed the work pieces on lathes correctly. Beyond this they were able to transfer the newly acquired method not only to the processing of new work pieces of the same class (shafts) but of work pieces of another class (bushings). The quality indicators relating to their work were the following: in 86.8 per cent of the cases they analyzed correctly the technological conditions determining the selection of a processing sequence; in 100 per cent of the cases they made a correct selection of a processing sequence; and in 100 per cent of the cases they carried out correctly the processing of work pieces on a lathe.

We see that in spite of substantial differences in the objects of the actions being assimilated (writing, chess, professional production skills) as well as in student age groups (preschool-age, elementary, and teen-agers) the results of learning were identical. Actions associated with the orienting basis of the third type were characterized by a rapid and practically errorless assimilation that remained stable when applied to new and widely differing conditions.

The fourth type of the orienting basis is characterized by the fact that guidelines are provided in a generalized form that relates to entire classes of actions rather than to individual cases. At the same time the system of guidelines is sufficiently comprehensive for a correct execution of the given action for all situations corresponding to the given class. Finally, the orienting basis is provided in a pre-established form, rather than being constructed autonomously by the subject.

Such a type of the orienting basis is usually employed in the development of logical actions that are independent of the object's concrete contents. As an example, let us consider the development of the action of associating objects with concepts, which we have employed repeatedly in forming concepts possessing a conjunctive structure of attributes. The assimilation of a specific concept (for example, of the bisectrix) resulted from the execution of problems requiring an associating of objects with the corresponding concept. In order that these problems be solved, it is necessary for the orienting basis of such actions to include not only the given concept's (i.e., the bisectrix) system of necessary and sufficient attributes but also the logical rule of associating. Such a rule, moreover, may be included either in a concrete form relevant to the given concept alone (an orienting basis of action of the second type) or in a general form suitable for associating objects with any concept possessing a conjunctive structure of attributes (an orienting basis of action of the fourth type). This is achieved by presenting the corresponding requirements not in a specific form that reflects the given concept's attributes (in the case of the bisectrix this would be: 1. a straight line, 2. it divides an angle into two equal parts), but in a general form (the object must possess the entire set of the given concept's necessary and sufficient attributes).

Similarly, the logical part, too, is presented in a general form rather than a particular form. In the case of the bisectrix the particular form would be the following: I. If the line: 1) is straight, 2) passes through the angle's vertex, 3) divides the angle into two equal parts, then it is a bisectrix; II. If the line: 1) is not straight, or 2) does not pass through the angle's vertex, or 3) does not divide the angle into two equal parts, it is not a bisectrix, etc.

In the case when its representation is generalized, the logical part of the orienting basis of recognition appears as follows: "The object is related to the given concept only if it possesses the entire system of necessary and sufficient attributes. This may be represented in terms of the following diagram:

$$\left.\begin{array}{l}1+\\2+\\\dots\\n+\end{array}\right|\quad +$$

"Should the object not possess even a single one of these attributes it does not belong to the given concept. In terms of that figure this is then represented as follows:

$$\left.\begin{array}{l}1+\ (?)\\2+\ (?)\\\dots\\n-\end{array}\right|\quad -$$

"If there is no information concerning one of these attributes while all other attributes are present, the answer remains uncertain: it is not known whether or not the object does belong to the given concept. This is represented as follows:

$$\left.\begin{array}{l}1+(?)\\2+(?)\\\dots\\n?\end{array}\right|\ ?$$

."

Studies have shown that when such an orienting basis is employed in developing the action of associating an object with a concept in relation to a particular concept, this action is then transferred without further learning to all other concepts possessing a similar logical structure of attributes. Each time, however, it is necessary to specify the new concept's specific system of necessary and sufficient attributes constituting the action's object-related (specific) part of the orienting basis, and each time these must be given in a pre-established form, i.e., in terms of the second type of the orienting basis of action (99; 164; 171).

Thus, in fact the orienting basis of the action of associating an object with a concept includes two parts: a specific one (a concrete system of attributes), designed in accordance with the second type of the orienting basis, and a logical one, in accordance with the fourth type of the orienting basis. It differs from the third type in that in this case the student encountering new concepts does not have to identify a new logical part each time but acquires it in a pre-established form when he assimilates the very first concept, and subsequently continues to be guided by that part in his work with all other concepts possessing the same structure of attributes. Unlike in the second type, however, these guiding elements are provided not in the particular form that characterizes the given concrete concept, but in a generalized form, and it is in that form that they enter into the contents of the logical part of the orienting basis of the action of associating objects with concepts. Thus, for example, in working with the concept an "island", the student thinks of the attribute "a part of dry land" as a "first attribute" and views the attribute "surrounded on all sides by water" as a second attribute. Of course, for each concept, it is necessary to establish which attribute should be viewed as first and which as second. In our case the students did not confront that problem since the concrete system of attributes that was given to them included a specification of their order.

In principle, the fifth type of the orienting basis of action may also exist. In it the student is given a system of guidelines that is insufficient for a correct execution of the action within the boundaries of the region determined by their degree of generalization.

An example is provided by the same logical part of the orienting basis of the recognition type of action in which it is given to students with certain guidelines missing. For example, the recognition of objects that do not belong to a given concept is limited by the following case:

$$\begin{array}{l|l} 1+ & \\ 2+ & - \\ \dots & \\ n- & \end{array}$$

Therefore, the orienting basis is incomplete: it does not permit a correct execution of the action of recognition in cases such as the following:

$$\begin{array}{l|l} 1+ & \\ 2? & - \\ \dots & \\ n- & \end{array}$$

The sixth type that we have listed is also possible. It differs from the preceding one only in that a generalized but incomplete orienting basis is derived autonomously by the student rather than given in a pre-established form. As in the preceding case actions guided by such an orienting basis will yield correct results in some cases and erroneous ones in others.

The seventh type of the orienting basis coincides with the second one in terms of two of its characteristics, namely, its particular form of guidelines and comprehensiveness, but differs from it in relation to the method through which the orienting basis is constructed. It is identified autonomously by the subject of action. This is characteristic, for example, of the actions of folk craftsmen, whose actions take into account the entire system of conditions that lead to an avoidance of errors and high-quality results even though the corresponding range of outcomes is extremely limited.

Finally, the eighth type of the orienting basis of action is also quite possible, in which a specific incomplete system of guidelines is provided in pre-established form. In our opinion, this is the most widely used type of guidelines in traditional forms of teaching. As a rule teachers provide specific instructions relating to such tasks as the writing of individual letters and the solution of specific problems. As a rule these guidelines do not encompass all the conditions that a correct execution of corresponding action requires and this produces errors.

The last five types of orientation call for further discussion and analysis.

2. *Possibilities for Programming Effective Types of the Orienting Basis of Action*

It has already been noted that the first four types of the orienting basis of action were subjected to experimental verification. This has shown that the third type is the most productive one. The fourth type was next, but its capacities are limited by the nature of the logical operations. Among the remaining types the second deserves attention. The second type of orientation may be effective in cases in which a rapid and errorless development of actions is needed to be applied to specific situations. Its advantage is that it is then relatively simple to identify the complete system of guidelines that effective actions under specified conditions objectively require.

It is probable that the other types of the orienting basis are merely of theoretical interest, in the sense that in principle they are possible variants. As for their effectiveness it may be asserted that types that possess only an inadequate orienting basis cannot be effective. The remaining seventh type appears to be close to the second one in terms of its effectiveness. The probability that this type will be used is quite low. In such cases the contents of the orienting basis are not programmed by teachers. They are discovered by persons executing the action. But to identify the full set of conditions that objectively determine the success of an action is a relatively difficult task even in given conditions.

It is not surprising that researchers have been giving particular attention to the third type of orientation. This corresponds most fully to contemporary norms in relation to human activities. Yet the need to identify the objective contents of conditions that lead to effective actions in particular areas represents a basic impediment to the programming of the orienting basis of this type. "The third type of orientation and learning calls for a much more comprehensive restructuring of various disciplines. The identification of basic units within the material and of the method for analyzing them as well as of general rules for combining them calls for an altogether different distribution and interpretation of materials than the one which is accepted in current methodology. Such a restructuring of disciplines is the principal impediment to applications of the third type" (38, p. 32).

How then is it possible to restructure the materials being studied in accordance with the requirements of applying the third type of the orienting basis?

Usually researchers follow an empirical approach in which they gradually note that which is common and essential and which underlies a multiplicity of particular phenomena within the given area. This usually requires much time and effort. As an example let us consider the restructuring of the rules of punctuation in the Russian language that was carried out by M. Ya. Mikulinskaya (104; 105).

At the present time the correct use of punctuation in Russian texts requires a knowledge of more than one hundred rules. Each rule is assimilated separately, i.e., only specific characteristics of the linguistic situation that are embodied in the given rule enter into the orienting basis that guides the action of recognition. These are the ones on which the student relies as he confronts the problem of placing punctuation signs in a proper manner. This represents an orienting basis of the second type. Since there are over a hundred such rules the time required to teach a student to apply each of them will become apparent, as will the difficulty of deciding which one should be applied in a particular case.

Mikulinskaya has analyzed these rules from the point of view of the functions that they perform and has shown that they are all concerned with three functions, namely, to combine (words or sentences), to distinguish (words or sentences), and to emphasize (words or sentences). This, then, is their essence, while the numerous rules are various forms in which that essence is expressed. In subsequent experimental courses Mikulinskaya taught students to be guided by the function that punctuation signs perform, i.e., taught them to recognize situations in which combinations, distinctions, or emphasis were sought and to develop appropriate systems of actions in each case, and then provided possible variants of signs that could be employed to perform each of these functions.

We thus see that in passing from the second type of the orienting basis to the third type, the contents of the teaching material as a whole change substantially, as do the contents of the orienting basis of action: instead of studying rules relating to the placing of punctuation signs, students are given knowledge concerning the *functions* of these rules; instead of developing actions bearing on the application of each individual rule the actions that are developed relate to a recognition of the relevant functions.

In a number of cases the use of the third type of orientation requires a restructuring of an entire series of subjects rather than merely of individual sections within some of them. A study carried out by Reshetova and Kaloshina provides an example. The objective was to train a non-specialized machine-tool operator so that he would be able to carry out all types of processing operations on several types of metal-cutting machines (lathe, milling, mortising). This required a knowledge of principles underlying all particular technologies and an ability to use these principles in identifying without further assistance specific procedures from a large number of theoretically possible ones. In such a context a single subject, namely, "Processing Technology for Machine Tools" replaced three more specific subjects ("Machine Tools", "Cutters", and "Technologies"). The logic of analysis was fundamentally changed: traditionally it had begun with machine tools and then moved to the work piece to be processed; in this case, however, the researchers considered the work piece first and then the machine tool. This made it possible to describe the machine tool as "a functional system, whose properties are determined by the work pieces for whose production it is designed" (131, p. 50). By then analyzing the principal technical parameters of individual work pieces—such as their geometric form, size, and the relative position of surfaces to be processed in relation to each other—the authors sought to identify the particular operational and functional features of the machine tool that related to these parameters.

This led to fundamental changes in the contents of the subjects being studied as well as of the students' activities. Instead of prepared expositions of the principles governing work with each individual machine tool students were taught to develop these principles themselves and were taught the corresponding method. So they were taught to develop an ability to elaborate autonomously the principles of machine-tool operation (the kinematics of the machine tool's operating parts) and of selecting cutters that are appropriate for producing work pieces of any specified form. In short, they were taught to solve problems in developing *methods* for shaping specified products.

Thus, basic structural units were identified from which the full diversity of particular situations could be derived as well as general rules for combining them in concrete situations. It emerged that for work pieces of any form the most general units were processing lines (not less than 2) which are combined in the light of principles that may be inferred, first, from their function (one is a forming function—this refers to a real line; the other is a directing line and is ideal—it defines the direction of movement of the forming one), second, from the angle (the forming line must lie at a specified angle in relation to the plane of the directing line) and third, from the line's form (lines may be of different forms). It is possible to arrive at the full set of possible surfaces by varying these factors one at a time or else in groups.

A system of actions was thus defined in terms of an orienting basis that included the fundamental properties and relations underlying all possible outputs that may be produced on machine tools, rather than properties of individual work pieces. This represents an orienting basis of the third type.

Naturally, students were given methods for identifying basic structural units. This permitted them to decompose any desired surface into basic units. But this is not yet sufficient to specify the corresponding properties of machine tools. Functional relations must be established between the machine tool's and cutter's structural elements, on the one hand, and the structural units of desired surface shapes, on the other. It emerged that specific elementary motions that are common to all machine tools correspond to specific surface lines of work pieces. The principles governing the grouping of such movements that produce a specific kinematics for the machine tool correspond to the principles governing combinations of lines. In general, moreover, the number of movements corresponds to the number of processing lines while the trajectory of such motions reflects the shape of processing lines.

After assimilating each of these elementary units and their relations students were able to develop on their own the principles that govern the operation of machine tools (the kinematics of their operating parts) and their cutting instruments (cutting edge) needed to produce a desired surface for any desired shape (74).

In analyzing the specific features of the third type of the orienting basis and the corresponding new structure of course subjects, Reshetova has shown that in fact a *systems-oriented* approach is then applied to the given area of knowledge (130; 131). This points to the possibility of designing orienting bases of the third type through a systems analysis of the subject being studied, rather than in empirical ways.

In a systems approach to the diversity of specific phenomena in a given area, the first step is to identify the system's *invariant* and to view individual cases as specific variants. "This is the principal task of analysis. It is concerned with a *reduction* of differences within a whole to a single generating basis, to their essence" (58, p. 311).

In the example that has just been considered the invariant associated with arriving at a work piece of any shape is represented by the forming and directing lines and by their mutual position in relation to each other, which is determined by the angle of the forming line in relation to the plane of the directing line. All possible variants of forms are produced by changing the shape of these lines and the angle of the forming line in relation to the plane of the directing line. It is the system's invariant that must be included into the action's orienting basis. This results in the following change in the contents of what is being taught: instead of studying a multiplicity of specific system variants that which is common and invariant is studied, which lies at the basis of each specific case. It follows that students who know the possible variants of invariant components and who possess method for identifying the invariant's components are able to both analyze new concrete phenomena and design them.

It is characteristic that students who develop activity procedures based on the third type of orientation (systems-oriented) are able to design by themselves not only known variants of a system, but new ones as well. In particular, in the study by Kaloshina and Reshetova that was mentioned earlier, ninth-grade secondary school students could identify on their own the kinematics of machine tools and shapes of cutting edges that do not yet exist but are in principle feasible, as well as those of many existing lathes and cutting instruments (74).[1]

Similarly, third-grade students who had been taught a systems-oriented approach in solving "process-oriented" problems in arithmetic, in the course of our joint experiment with G. Nikola, were able to design a large number of new problems and solve their new variants (109).

All this indicates that this type of the orienting basis is most effective in developing a capacity for creative thinking.[2] But it is also very important that students then acquire an ability to apply a systems approach to the subject, for this makes them able to anticipate new situations in a given area and to orient themselves within such situations without additional learning.

The very great advantages of the third type of the orienting basis include the fact that they free individuals from the need to study each particular phenomenon in a given field. This represents a shift to a new method for storing information: instead of a diversity of established particular facts and specific methods for analyzing them a single method is given. It is assimilated in relation to a number of particular phenomena (their number need not exceed the requirements of assimilating that method), but subsequently, it permits individuals to design independently any specific manifestation of the corresponding system.

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[1] Similarly, it is characteristic that members of a control group that included vocational instructors (4 persons), specialists possessing a post-secondary technical education (25 persons) and students specializing in the design of machine tools (25 persons) were unable to develop new methods for solving specified problems.

[2] Genuinely creative thinking occurs when a person identifies on his own an invariant of the system that he is considering together with an appropriate method. In our case it is the teacher who plays such a creative role. But systematic instruction activities of this type will substantially enhance the creative ability of the students.

A comparative analysis of the second and third types of orientation, raised up to a philosophical level, has been done by V. V. Davydov (58). In this connection he has shown persuasively that the second type of the orienting basis refers to an orientation on phenomena rather than on their essence. Such a type of orientation produces empirical thinking, while conversely, the third type leads to theoretical thinking. "To learn the essence means to find what is common as a basis and as a single source of a certain variety of phenomena, and then to show that this common basis determines the emergence of phenomena and of relations among them, i.e., the existence of concreteness" (*Ibid.*, p. 311).

It has been shown that orienting bases of the third type provide for such an approach to knowledge. But students do not find what is common (the essence) by themselves. They receive that knowledge from teachers in the form of an orienting basis of actions. They perceive it by analyzing a variety of phenomena as manifestations of that which is common (their essence). In other words, they assimilate an essence through phenomena. In such a context the latter perform a new function: they serve as a means for assimilating the essence that has generated them, rather than as objects of assimilation.

This is also true of the manner in which activity itself is oriented. It has already been noted that the students' orienting basis of action must contain necessary information concerning the particular activity that he is expected to carry out. This information may be conveyed in a concrete form that is relevant to the execution of only the given activity. In such cases the student finds himself in the position of the figure from Molière who was not aware that he was speaking in prose. But it is also possible to convey the orientation relating to a specified activity on a fundamentally different level, namely that of its structural and functional characteristics. In such cases in orienting themselves in relation to a specific activity students will view it in the light of activity in general. The resulting activity then appears as a means for assimilating the structural-functional characteristics of any human activity. Subsequently, this makes it possible to organize new types of activities without further assistance (135).

These and later studies (I. I. Ilyasov) have shown that an activities-oriented approach to the process of learning provides a basis for a constructive approach to the problem of "teaching to learn". It was found that an orienting basis must then be given not only in relation to the structural-functional characteristics of activity, but to the logic of formation stages of new types of cognitive activities as well.

Finally, studies of relations among individual elements of actions have made it possible to approach the problem of a goal-oriented development of creative types of activity. In the study by I. P. Kaloshina and N. A. Dobrovolskaya it is shown that students who orient themselves on the structural characteristics of activities are able to identify without further help the relations that exist among their individual elements, while a knowledge of such relationships makes it possible to identify others that are initially unknown.[1]

This analysis shows that whenever this is possible actions (activities) should be programmed in terms of an orienting basis of the third type. This makes it possible to raise the effectiveness of instruction to a radically new level.

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[1] This study was concerned with problems whose solutions required the development of additional structures. In the past the selection of a particular additional construction remained a mystery; it was not clear how a person arrived at the thought that additional structures must be of a particular type rather than of another. The analysis that was carried out by the authors has shown that the further development of additional structures within a given structure of activities always operates as instruments. These are related to the outcomes of activities in a specific way. Thus, a knowledge of the corresponding features of outcomes makes it possible to identify the required instruments. Members of the experimental group developed activities needed for analyzing the structure of activity and for establishing relations among its elements. Having mastered that activity they were able to find independently the corresponding relation between outcomes and instruments of activity. With the help of that relationship and knowing the specification of the outcome they found the necessary instruments, namely, specific auxiliary constructions.

§ 4. The Stages of Development of Mental Actions

A knowledge of the structure, functions and basic characteristics of actions makes it possible to model the most rational types of cognitive activity and to identify the specifications that mark the conclusion of a learning process. In order that programmed types of cognitive activities be assimilated by the learner they must pass to a number of distinct states that are qualitatively specific in terms of each of their basic characteristics. Before an action becomes mental, generalized, condensed, and assimilated it passes through transitional states. Such major transitional states constitute stages in the assimilation of actions, each being characterized by an aggregate of changes in the action's basic properties (parameters).

The theory under consideration distinguishes five stages in the process of assimilating fundamentally new actions (36; 38; and others). In recent years Galperin has pointed to the need for introducing still another stage, whose principal task is to create the necessary motivation in the student. Whether or not the solution of that problem constitutes an independent stage, the presence of motives required for causing a problem to be accepted by students and to be resolved in an adequate manner must be assured. If they are not present, the corresponding actions and the required knowledge will not be developed. (It is well known that if a student does not wish to learn he cannot be taught.) In order to create positive motivations problem situations are usually created whose solution requires the particular action that one wishes to develop.

1. Characteristics of the Major Stages in the Process of Assimilation

At the *first stage* students receive necessary clarifications concerning the objective to which the action relates, its object and the system of guidelines. This stage is concerned with an initial familiarization with the action and the conditions under which it can be carried out. It represents a *stage of formation of an outline of the action's orienting basis.*[1]

The significance of that stage in the action's development is very considerable. It is at that point that the orienting basis of action is perceived by the student, that an introduction to the object of study is presented, and that students are shown in what way and in what sequence the three types of operations required by an action are carried out (the orienting operations, the executive ones, and the control operations). Depending on the type of orienting basis students are either given the basic elements that underlie all specific manifestations in the given area of knowledge or the characteristic features of a specific manifestation.

At that stage the teacher externalizes his mental actions and displays them to the students in a material or materialized form. Students, on the other hand, who have not yet mastered this action to any significant extent rely on actions that were developed earlier (largely in a perceptive and mental form) and elaborate an orienting basis for a new action. This is not yet an action but merely a familiarization with it and with the conditions needed for its successful execution. This makes it possible to understand the logic of that action and possibilities for carrying it out.

"Whatever the quality of the orienting basis may be and whatever the form in which it is provided—either as a conception or as an external outline—it remains no more than a system of instructions concerning how the new action should be carried out, and is not the action itself. The student has not yet performed an action and has not even begun to produce it. Yet without performing an action one fails to assimilate it" (36).

It is particularly important to emphasize the distinction between understanding how to act and the actual ability of acting, since it is widely thought in the practice of teaching that if a student has understood he has also learned and that the objective has been reached. In fact, the assimilation of an action (activity) takes place only when the student himself performs that action and not when he observes the actions of others. This is why the present theory identifies four more stages following the initial one, which refer to the execution of actions, being assimilated, by students themselves.

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[1] In the studies by Galperin that stage has been given several names. At first it was called "the stage of development of a preliminary conception concerning the assignment" (32); then it was called "the stage of clarifying the orienting basis of action" (38, p. 37); later still it was called "the stage of familiarization with the action's objective conditions and their representation in the form of a plan recorded in summary form on a card" (38). At the present time Galperin refers to the first stage as the stage of working out an outline of an orienting basis of action. We see that as these names evolved they have increasingly emphasized its principal contents.

The second stage refers to the development of action in a *material (or else materialized)* form.[1] Students already carry out actions, but for the time being they still do this in a material (or else materialized) form and with an extensive specification of all component operations. The orienting, executive and control components of the action are all performed in such a form. That stage permits students to assimilate the action's contents and permits the teacher to carry out an objective control over the execution of each component operation.

In order to generalize the action, the teaching programme includes problems that reflect typical situations in which the given action is appropriate. There should not, however, be many similar problems at this stage since this may produce a condensation and automation of action. Neither should take place at this particular stage. In other words, at that particular stage students assimilate actions that are material (or else materialized), extensive and generalized within the framework of major types of examples, and perform all component operations in a conscious manner (40).

At that stage a preparation should also take place to move the action to the subsequent stage, which differs from the preceding one above all in the form of action. To achieve this from the very first the material (or else materialized) form of action is combined with the verbal form: students formulate verbally everything that they carry out in practice, that is, materially.

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[1] The names of the second and subsequent stages correspond to the names of forms of action. Yet, the content of the concept of a form of action and that of a stage of its development differ: a change in the form of action refers to a change in merely one of its parameters, while changes in the stage relate to all four parameters.

Once the action's entire contents have been assimilated it must be moved to the next or *third stage*, namely, *the stage at which actions are developed in the form of external speech.*[1] At that stage, in which all elements of action are represented in the form of external speech, the action experiences a further generalization. It is still, however, unautomated and uncondensed.

At that stage speech begins to perform a new function. "In the first and second stages, speech served primarily as a system of pointers to phenomena that gradually became directly evident in perception; it was the task of the student to discern not the words but the phenomena, and to orient himself in relation to them and master them. Now, however, speech becomes an independent embodiment of the entire process, including both the task and the action" (36, p. 455). Speech actions must always be assimilated in extensive form: all component operations must not only acquire a speech form, but be assimilated in that form. Generalized actions acquire new capacities at that stage which are provided by the speech form of action. In particular, new typical situations may be conveyed with the help of speech that could not have existed at the preceding stage. In developing the action of associating an object with a concept, for example, generalizations are limited to two situations at the preceding stage, namely, the one in which the object does belong to a given class, and the one in which it does not. At the third stage, however, actions may be generalized by introducing situations with incomplete conditions. At its concluding phase actions begin to be carried out with omissions of individual speech form operations. In principle this may represent the beginning of a genuine condensation of actions (i.e., operations are not carried out but are kept in mind), but it may also represent a transition of operations to a mental form. In such a case, there is no condensation of actions. All operations are carried out, but some of them have acquired a new form.[1] At the external speech stage actions should not be carried to the level of automation.

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[1] In the studies by Galperin that stage is called the stage of development of actions in voiced speech (38, p. 37). But it has already been noted (see Paragraph 2 in the present chapter) that in a number of studies the written speech form was employed successfully. Since we have therefore changed the name of the corresponding form of action we will also change the name of the corresponding stage.

The fourth stage is the stage at which actions are developed as unvoiced external speech. It differs from the preceding one in that the action is carried out silently and without writing as being expressed within oneself. Initially, the action does not differ from the preceding stage in terms of its other characteristics (extensiveness, consciousness, and state of generalization). Nevertheless, once they assume a mental form actions begin to rapidly experience reduction and automation and acquire the form of operation conforming to a formula (*Ibid.*, p. 457).

From that moment actions move to the concluding *fifth stage—the stage of development of actions in internal speech.*

At that point they rapidly acquire an automated form and become inaccessible to self-observation. They are now acts of the mind within which the process is hidden and only its outcome lends itself to awareness: "within the newly formed mental action nearly all of its actual contents are removed from consciousness, and that which remains within it cannot be understood correctly without being related to the rest" (*Ibid.*, p. 458).

In this way, mental actions, which are so unlike the external material actions that generated them, are products of the latter's stage-by-stage transformation. "A stage-by-stage development of ideal, and in particular of mental actions, relates psychic activities to external object-oriented material activities. It provides a key not only to understanding psychic phenomena but to their practical mastery as well" (*Ibid.*, p. 466).

Since these stages are characterized by a set of indicators relating to all four parameters, there naturally arises the problem of specifying values for each of them at each of the stages. It has been noted, however, that qualitative changes have been identified for only one of the four characteristics, namely, form, and that for the present they remain unknown for the other three. Since changes in the form of action play a leading role, they also play the role of indicators of transitions from one stage to another.

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[1] In noting such a change in action Galperin describes it as a condensation. In our own view, however, the grounds for stating this at the present time are insufficient, since the omission of a speech form operation can be explained both by a condensation of the action and the operation's transition to the next genetic form. This is, in fact, noted by Galperin, when he writes that "the essence of the mechanism of reduction is this: initially for a very limited sector material actions are replaced by ideal actions (viewing, attention)" (38, p. 8). Since at the present time there are no methods for establishing the nature of such changes with certainty this remains a problem area.

As for other characteristics, several points may be noted. First, the action in each new form must initially be fully extensive: all component elements must experience a transformation in form. Second, at no stage except the last one should the assimilation of actions be carried to the point of automation. This means that the basic characteristics of action influence each other as they develop: the automation of action in one of its preceding forms inhibits its transition to genetically more advanced forms. Their (material) form constrains possibilities for their generalization.

2. The Organization of Control (Evaluation and Correction) Over the Process of Assimilation

In the stage-by-stage development of mental actions the organization of control represents a special problem. Galperin's view that attention represents an internal control implies that external control must be gradually replaced by internal control and must be transformed at the concluding stage into an act of attention. "The operation of control is transformed into attention which from the point of view of direct observation (intraspection) appears as a kind of activity, i.e., an aspect of (our own) working action that cannot be defined more closely (*Ibid.*, p. 460).

In organizing the control component of actions it is necessary to know what type of control must be exercised (whether it should relate to individual operations or to their final outcome), how frequently it must be exercised (in relation to each task or only some of them). Finally, external control may be carried out either by the students themselves or by another person (a teacher or, for example, a neighbouring student).

In order to study the influence of all these factors on learning effectiveness, we have carried out a special experimental project together with S. El Hodarie. This related to the development of the actions of associating objects with concepts as applied to the teaching of elementary geometric concepts (rays, segments, angles, bisectrices, perpendicular lines). The group included 72 third-grade students from Moscow School No. 194.

More specifically, these studies were concerned with the relative effectiveness of control over individual operations *vs.* control in terms of final outcomes, as well as of systematic control *vs.* occasional control (i.e., applied to 50 per cent of the cases). Also of external control by teachers and other students *vs.* self-control. These factors, moreover, were not studied in isolation from each other. A "comprehensive factor approach" was employed.

The students were divided into 12 groups in accordance with selected factors. Each group and each student were simultaneously subjected to the influence of all three specified factors. Subsequently, all students were given the same check tests whose purpose was to check the quality of the action that had been developed in terms of the following indicators: the correctness of its execution, the time required, the attained form of action, the degree of awareness, its state of generalization, its rationality, and its stability (this was verified again three months later). In addition, visual observations during the course of learning and conversations with students made it possible to acquire some information concerning the students' motivation.

The findings indicated that with regard to all recorded characteristics control in terms of operations was more effective than control in terms of final answers.

The influence of the frequency of external forms of control was shown to be ambiguous. Occasional control led to a deterioration of the quality of assimilation in terms of form, degree of assimilation and stability. But no significant differences were found with regard to the elements of awareness, rationality, and extent of generalization. Tests relating to influences on motivation indicated the following: non-systematic control at the stage of materialized actions and external verbal actions (especially during the first phases) caused negative attitudes on the part of students. Subsequently the use of occasional control did not cause negative attitudes. Conversely, systematic external forms of control produced negative reactions towards the end of the external speech stage and at the stage of external unvoiced speech.

These findings indicate that the required frequency of external control depends on the stage of assimilation, and also that it must be changed within individual stages. This may be easily explained: at the beginning of the materialized stage, and at the beginning of the external speech stage, students assimilate new forms of action and require systematic control. Towards the end of these stages the corresponding forms have already been assimilated and systematic control in external form is therefore no longer needed: it is carried in internal form. Gradually, the control component of actions is transformed into acts of attention. This is why the introduction of external forms of control at that stage produces negative attitudes. A similar situation exists at the stage of external unvoiced speech: since there are then no substantial qualitative changes in the form of action students do not need systematic external control. Self-control is then sufficient.

Still another important finding was recorded: systematic control produces a positive influence at these stages only when it is executed in terms of individual operations. If, on the other hand, control is carried out in relation to final results its systematic character exerts no perceptible influence on the quality of assimilation. Apparently this is explained by the fact that an absence of control over individual operations greatly impedes the process of assimilation by not permitting timely corrections in its course; in such a context the introduction of systematic control over the outcome of actions does not add anything to the situation.[1]

As for the third factor being examined, namely, the method through which control is effected, no significant differences were found among various groups with regard to the quality of assimilation. But a comparison in terms of the quality of the course of that process shows that control by the teacher is more effective than is self-control or control by other students both in those groups in which control activities related to the final answer and in those in which they were occasional. In the case of systematic control over individual operations there were no significant differences among groups: control by teachers, by other students, and external self-control yielded the same results. As for the attitude of students to methods of control the following was found: self-control and also control by other students produced a positive attitude while control by teachers did not produce any particular reaction. It is possible that this difference in attitudes is explained by the element of novelty: control on the part of teachers is familiar, while other forms of control are new. It should also be noted that positive attitudes in groups in which the students worked in pairs that controlled each other in turn were more stable than in groups relying on self-control (193).

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[1] The non-relevance of the frequency of control activities in cases in which control relates to final outcome has also been shown by many other researchers: cf. Chapter Six, § 5.

This study thus makes it possible to formulate the following requirements relating to the organization of control activities:

1. During the initial stages of the process of assimilation control activities should relate to individual operations.
2. At the beginning of the material (materialized) and external speech stages external control should be systematic and relate to each assignment.
3. At the end of these stages and also at the subsequent stages, such control activities should be occasional as required by the student.
4. The particular method of effecting control (who controls) does not have a fundamental influence on the quality of assimilation. At the same time the element of novelty in forms of control and a reliance on competitive situations (in which students work in pairs, and control each other in turn) contribute to the creation of a positive learning motivation.

3. The Role of Individual Assimilation Stages in the Development of Actions

The identification of the major stages in the process of assimilation raises the following question: what is the role of each in the development of actions, and is it possible to omit individual stages in developing particular actions?

Two cases should be distinguished in examining this problem: a) the possibility of omitting stages in utilizing a previously developed action for purposes of assimilating new knowledge; b) the possibility of omitting stages in the development of a new action to assimilate new knowledge.

Let us begin our analysis with the first case.

Two of our studies (99; 164) were concerned with the action of associating objects with concepts. The concepts in question were "a straight line" and "an angle". The members of the group were fifth- and sixth-grade students whose performance had been low or average. The action was carried through all stages of the assimilation process.

Only a specific concept and one representation of a figure belonging to that concept was presented in developing the following concepts: "bisectrix", "perpendicular line" and "adjacent angles". The students were asked to infer necessary and sufficient attributes from the corresponding definitions and to pass immediately to the mental stage in solving a number of problems relating to the association of objects with these concepts. The problems were given in written form. In terms of their contents and of the relation of drawing to specified conditions, they were divided into four types: 1) problems with sufficient conditions and adequate drawings; 2) those with sufficient conditions but inadequate drawings; 3) problems with inadequate conditions and adequate drawings (all possible cases corresponding to the problems conditions); 4) problems with inadequate conditions and inadequate drawings.

Problems also varied in complexity: in some cases only one of the relevant concepts was given and the concept's attributes were presented explicitly; in others the relevant concept was given within a system of concepts and its attributes were presented indirectly by specifying relations among individual concepts, including concepts that were unfamiliar to the student.

It was found that all students were able to answer the problems correctly. The occasional errors that were made were corrected by the students themselves, and there were only three such errors (1.7 per cent) in 176 solutions, involving applications of the concept "adjacent angles".

In check tests the object of action was presented in external speech form (a written specification of conditions). The students were expected to remember the attributes that were relevant to the problem's solution. It emerged that the students answered different problems at different levels (stages). The simpler ones were answered at the mental level while the more complex ones were solved at the external verbal level (with a voiced listing of attributes and reasoning). In solving problems relating to the application of attributes of the concept "bisectrix" only 4 out of 110 solutions were carried out at the external verbal stage (3.6 per cent). But in solving problems relating to the application of attributes of the next concept, namely that of "adjacent angles", 120 out of 176 solutions were carried out with the help of spoken words (68.2 per cent). In carrying out problems relating to the application of the third concept, namely that of "perpendicular lines" the absolute majority of problems were solved at the level of internal speech: only 16 out of 198 problems were solved with the help of spoken words (8.1 per cent). This may be explained by the fact that the concept "adjacent angles" possesses a larger number of attributes than the other two concepts. Apparently, it is difficult to select and compare large numbers of attributes in one's mind and students shift to the use of spoken words.

It also became apparent that most of the solutions that were carried out at the external verbal level related to problems whose conditions were inadequately defined. This always produced greater difficulties among students than other types of problems.

Thus it was found that the development of new concepts on the basis of previously formed actions may take place with omissions of several stages, and that the number of omitted stages is determined by the complexity of the problems: as problems increase in complexity the next stage will be closer to the initial form of action.

It may seem at first that these findings show that not all the stages that we have considered are mandatory. But that is not the case. For the action of associating an object with a concept had already passed through a stage-by-stage transformation in relation to other concepts. The use of that action with regard to new concepts requires only a partial change in the orienting basis of this action. Indeed, in associating objects with the concept an "angle" students have to orient themselves first on the necessary and sufficient attributes of an angle and then on the logical rule of association. The logical part of the orienting basis of action and the operations associated with that action in work with earlier concepts were immediately developed in a generalized form (in terms of the fourth type of orientation) which is suitable for recognizing objects belonging to any concept possessing the same structure of attributes. Since the action, including its logical part, was carried to the mental level, it is natural that in the development of subsequent concepts that part of the action may then be employed as an acquired means. Only the specific part of the action of associating an object with a concept will be new, namely, the specific system of attributes that is sufficient for identifying objects of the given class and the methods for identifying them within objects.

Thus, in fact, the given action proved to be only partly new, and it was the new part that had to be subjected to a stage-by-stage transformation. This was not required by its other elements.

Thus, a knowledge of an action's structure, of its "past", and of the new conditions within which it is to be applied makes it possible to determine purely analytically which of its elements will require a full stage-by-stage processing within the new conditions and which may be applied immediately at the level of higher stages.

The case that we have considered is not typical, for the role of various stages in the development of an action may be traced in a pure form the very first time it is introduced into the learning process. Such cases were studied by P. Ya. Galperin and N. D. Kadymova (73), and by the present author and V. V. Nikolayeva (173).

The first of these studies was concerned with the development of the concept "perpendicular lines". The stage of materialized action was omitted by some students, others omitted the external speech stage, while still others omitted the stage of mental action. [1] Finally, a fourth group of students relied exclusively on the first and last stages, i.e., they passed immediately to the stage of mental action

Experiments have shown that while the assimilation of actions and of corresponding concepts is possible with omissions of individual stages, this presumes a comprehensive development of all the others. The omission of different stages influences the course of the learning process in different ways. Thus, in the case under consideration the omission of the stage of mental action exerted no influence on the quality of learning. The omission of the external speech stage exerted a negative influence on the stage of mental action: actions at that stage required much more time than normally, remained extensive in form, and became automated more slowly. This expressed itself in the fact that in passing to the stage of "unvoiced" actions, solutions to problems were carried out much more slowly, unlike in cases in which all processing stages were carried out.

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[1] At that time (1955) the external unspoken stage was not yet viewed as a distinct one.

The consequences of omitting the materialized stage were especially evident. In such cases students initially did not employ the attributes that had been given to them verbally, even though they could list them without errors. The researcher found it necessary to continually recall these attributes, to insist that they be applied, and to provide additional explanations. As a result the external speech stage was considerably lengthened. When both the material and the external speech stages were omitted it was not possible to develop the corresponding action and concept.

This study has thus shown that the initial stages in the development of actions are much more important than the final ones. In the initial stages actions experience major transformations in form: they are assimilated in a material (materialized) form and transformed into a verbal form. Subsequent transformations in form are less important; at the last stages (external unvoiced verbal forms and mental forms) actions remain verbal and all changes take place within the verbal form—from the external verbal form they are transformed into the mental form with the help of internal speech.

In analyzing the results of that study it is important to note that in assimilating the initial form of an action its materialization was incomplete: the orienting basis of action was limited to a system of essential attributes listed on a card, i.e., presented in a speech form. As a result the process of relating attributes to objects was not materialized: drawings served as objects and they naturally could not be compared with conceptually specified attributes. It is, therefore, not possible to accept the findings of that study as fully conclusive.

The objective of our joint study with V. V. Nikolayeva was to clarify the specific features that characterize the development of actions of associating objects with concepts in situations in which the external speech stage and the stage of external unvoiced speech were omitted, and in which the initial form of action varied with the group. That study referred to elementary geometric concepts such as "straight line", "angle", "perpendicular line", "adjacent angles". Three groups of students participated in the experiments (fifth-grade students of average performance). There were ten persons in each group. The methodology that was employed in each group differed only in the following respect: for the first group the initial action was material in all its elements (students were concerned with real objects). In the second and third groups the initial action was materialized: students in the second group referred to spatial models, while students in the third group to drawings. In addition half the members of each group (sub-group A) were given a card at the stage of material (or materialized) actions, on which the essential attributes of the concepts in question were written in a specific order. The second half of each group (sub-group B) only heard oral enumerations of these attributes.

In all other respects the teaching methodology was identical. Following the mastering of the action in material (or else materialized) form students shifted immediately to its mastering in mental form bypassing the external speech stage and the external unvoiced speech stage.

In mastering the initial form of action students were given either objects (Group I), models (Group II) or drawings (Group III) to be associated with the concept being developed; at the stage of mental action all students were given problems in written form, without drawings, requiring that objects be associated with concepts; moreover there were more problems requiring actions in the mental form (twice as many) than are usually given to students for mastering it at all stages. The total number of problems solved by students was thus the same as in cases in which indicated stages were not omitted.

All students were subsequently given the same series of check tests concerned with actions of associating objects with concepts in different situations.

The results produced by the learning series of experiments are given in Table 3 (second series of experiments). Results obtained in another study are also presented in that

Table 3

Results	Series I						Series II					
	Group I		Group II		Group III		Group I		Group II		Group III	
	A	B	A	B	A	B	A	B	A	B	A	B
Number of correctly solved problems	299	295	293	291	286	259	240	225	245	230	199	170
Number of incorrectly solved problems	16	20	22	24	29	56	75	90	70	85	116	145
Per cent of incorrectly solved problems in relation to problems assigned	5.1	6.3	7.6	7.6	9.2	17.4	23.8	28.7	22.2	27.0	36.8	46.0

table (the first series of experiments) in which the action of associating objects with concepts was developed without omitting any stage (172). This, too, refers to a group of 30 students. Each sub-group was given 315 problems. It may be seen from the table that the omission of the external speech stage and the external unvoiced speech stage inhibits the process of action development: there were 3-4 times as many errors in the second series as in the first, in which no stages were omitted. A comparison of results in terms of the second series shows that the omission of the external speech stage was least significant for students in the second group, whose initial form of action referred to models. The fact that there are somewhat fewer errors in that group than in the first, "real objects-oriented" group, is probably explained by the circumstance that the models specified those geometric relations that were important for the action of associating objects with concepts. As a result the transition from models to concepts and the process of abstracting from nonessential attributes required less effort than in the case of objects in which attributes that are essential for the action are merged with a large number of nonessential attributes. As in the case of the first series the results of the third group were much worse. Its members were given drawings, and as a result they were able to associate sample items with objects only visually. Thus, the data of the second series of experiments confirm once more the importance of providing for active manipulation at an action's initial stage. In all sub-groups in which students were given a card with a system of essential attributes when mastering the action in the initial form (sub-group A), the results were better than in those sub-groups to which no cards were given (sub-group B). This is explained by the fact that when the card is available at the stage of material (or materialized) action a part of the orienting basis of action is mastered not only in a material (or else materialized) form but also in a speech form, and this facilitates a transition to the mental form of action. The students' achievements at various stages are recorded in Table 4 (the first series refers to cases in which all stages of action were mastered, while in the second series the external speech form was omitted). The table shows that most of the errors made by students in the second series occur at the stage of mental action. This points to the difficulty of

Table 4

Results by stages	Series I						Series II					
	Group I		Group II		Group III		Group I		Group II		Group III	
	A	B	A	B	A	B	A	B	A	B	A	B
Number of errors at the initial stage	1	0	5	6	8	15	0	0	4	3	4	2
Number of errors at the external speech stage	11	15	16	13	17	28	—	—	—	—	—	—
Number of errors at the stage of mental action	4	5	1	5	4	13	75	90	66	82	112	143

a direct transition from the stage of material (materialized) action to that stage.

At the initial stage of action there are few errors in both the second and the first series.[1] Most errors in the first series occurred at the external speech stage, at which the assimilation of action in a speech form first takes place. At the stage of mental action there are fewer errors. This indicates that a transition to that form is not difficult once the external speech form has been developed. In the second series of experiments, in which the external speech form was omitted, nearly all errors occurred at the mental stage of action. It is characteristic that the number of errors at that stage, when the external speech form and the "unvoiced external speech form" (Series II) were omitted, is much greater than for the external speech stage and the stage of mental actions taken together for the case in which all forms of action are assimilated (Series I). The omission of the external speech form of action inhibits the development of action in mental form. It is interesting that when they were correcting errors made at the stage of action in the "unvoiced" form, students shifted spontaneously to a voicing of solutions. Many students sought to represent the conditions specified in the problem through diagrams and students from the first ("object-oriented") group sought to rely on external objects in their surroundings.

The number of errors made by students is distributed unevenly, not only among stages but also among concepts (Table 5).

Table 5

Concepts	Group I		Group II		Group III		Total number of errors
	A	B	A	B	A	B	
Straight line	25	30	26	29	43	50	203
Angle	11	17	9	9	20	24	90
Perpendicular line	9	14	14	18	20	28	103
Adjacent angles	30	29	21	29	33	43	185

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[1] It is not clear why in both series of experiments actions with models proved to be more difficult than actions with real objects. It may be because the real objects were familiar to students (books, tables, ink wells, etc.) while they encountered models for the first time.

For all sub-groups (except I A) the greatest number of errors is associated with the very first concept, namely a "straight line". Having partly assimilated the action of associating an object with a concept (in an "unvoiced" form) in such a context students experience fewer difficulties in working with the concepts of an "angle" and of a "perpendicular line". But in encountering the more complicated concept of "adjacent angles", which possesses three essential attributes, the number of errors in carrying out actions in mental form increased sharply once again.

The check tests required members of all groups to carry out the action of associating an object with a concept in different forms, including the materialized, external speech form, and mental form. Except for Group III, there were no significant differences in the responses among various groups. Nor did the omission of indicated stages lead to a substantial deterioration in results (a comparison was made with the first series of experiments in which there were no omissions).

While members of the third group were successful in solving problems calling for an orientation on concrete objects, they experienced substantial difficulties in solving problems calling for an orientation on concepts. The performance of sub-group III B was especially poor. There it was in fact not possible to arrive at satisfactory actions.

The outcomes of the teaching series of experiments and check tests make it possible to arrive at the following conclusions:

1. The omission of the external speech stage of action inhibits the process of its development substantially, even when the organization of action assimilation at other stages is comprehensive; this occurs, moreover, for any initial form of action.

2. The omission of the external speech stage of action inhibits the process of abstraction from nonessential properties, without which an action cannot be translated into a conceptual form. As a result, those groups suffered least from an omission of the external speech stage of action in which the initial action was mastered in terms of models. In all sub-groups in which students were given a card at the stage of material (or else materialized) actions on which the attributes of the concepts in question were represented the consequences of omitting the external speech stage of

action were less pronounced than in other sub-groups, since this produced a partial mastering of action in an external speech form.

3. It is not possible to arrive at a successful development of a concept at the stage of material (materialized) action in cases in which the active use of hands and the use of cards listing essential concept attributes are excluded.

The results of this study thus generally coincide with those of Galperin and Kadymova: the omission of the external speech stage seriously inhibits the development of the action of associating objects with concepts.

Beyond this, the replacement of material operations by perceptive ones at the material stage in fact produces the same result as the omission of that stage itself. Indeed, in the first study it was not possible to develop concepts when the material and external speech stages were omitted. In the second study the same result was produced by omitting the external speech stage and excluding the use of hands at the material stage.

While emphasizing the significance of the material (materialized) stage in developing new actions, it should nevertheless be noted that the introduction of objects and models into the teaching process, followed by their abandonment, is not always equivalent to the organization of a material (materialized) stage of action.

In the case of many production skills, for example, it is necessary to create an orientation on a muscular effort, and to some extent this must therefore be included into the orienting basis of action. The required level of muscular effort is then measured and recorded on a scale connected to dynamometer. The units employed for such a recording are then employed by students as an external material guideline: when performing the corresponding action they increase their muscular effort to the level at which the moving hand of the instrument reaches the indicated level (external guideline).

Such a material external representation of a guideline makes it possible to develop specified levels of muscular effort. This makes it possible for students to experience a kinesthetic feeling of that effort. After a number of repetitions the feeling is remembered. It may then serve as an internal guideline in arriving at a specified level of muscular effort. The external guideline in the form of a scale and pointer are then no longer necessary (155). But in this case we cannot say that the internal guideline is acquired through a stage-by-stage transformation of the external one. The problem was not to develop a kinesthetic feeling but only to actualize it. In such a case the external guideline helped the student to activate the required level of muscular effort, and hence the corresponding feeling, which then replaced the former, but did not cause its transformation.

On the other hand, it is not always possible to represent all elements of a developing action in an external material (or materialized) form. For example, in developing the action of analyzing sounds the objects of action are words. The orienting basis of action contains sample sounds constituting a word, as well as their number and sequence within a word. The executive part is concerned with dividing words into sounds and an identification of their sequence.

Studies usually partly materialize the object of action and its orienting basis. Thus in the study by Elkonin (187) a spatial-graphic figure was presented for that purpose that modelled a number of component sounds. In addition the outcomes of the executive part were materialized: each correctly identified sound was recorded on the spatial model of that word with the help of a label. The executive operations were not materialized: from the very first sounds were identified in a perceptive audible form. Students were guided towards a system of executive operations with the help of special procedures. In such cases the guidance of the corresponding action's development is incomplete and does not encompass all its elements. It should be emphasized as well that such a guiding process is possible only in cases in which the corresponding system of cognitive actions has already been developed as a result of earlier experience.

This description of the stage-by-stage development of mental actions cannot be viewed as complete. It does not reflect sufficiently changes in action in terms of each relevant parameter: we have only considered one of them, namely, form; the "behaviour" of other parameters at each of the indicated stages has not yet been sufficiently studied. It is the task of subsequent research to identify qualitative changes in each. At the present time this has only been done in relation to the form of actions. This is insufficient for an understanding of the process through which internal mental actions emerge.

As H. Wallon (322) correctly observes, in order to understand the principles that govern the development of psychic actions it is very important to know the dynamics of transitions. This is more important, in his view, than to know the forms that have developed, or to possess a static description of the process's basic stages. At the present time the dynamics of transitions of actions from stage to stage have also been studied insufficiently. Data that have been accumulated in the course of various experimental studies merely indicate that transitions from one stage to another vary in difficulty. Transitions from the material stage to the external speech stage are especially difficult, and it would appear that they should take place gradually both in their qualitative aspects, and, if this is appropriate, quantitatively as well.

The gradual character of transitions along the first of these lines primarily refers to the fact that a translation of the material form of action into an external speech form frequently requires intermediate transformations along that parameter. For example, if at the second stage the objects of actions are material objects or else corresponding drawings, a transition to a conceptual object specified in an external speech form frequently requires an initial transition to models, sketches and drawings and only then to a verbal object of action (47; 112). Similarly, a transition from manual operations (practical) to verbal (theoretical) operations sometimes takes place more easily through a perceptive form, i.e., through theoretical operations carried out visually with the support of material or else materialized objects (44; 45).

Forms of transition between objects (or else their representations) and words, which represent a qualitatively new objects of action produce the conditions that are needed to identify and abstract those specific aspects of real objects that are the objects of action and must be embodied into words.

Special studies are needed of the conditions under which the process of abstraction occurs most quickly. In this connection comparisons of different methods for materializing orienting bases of action and objects of action are useful. The results of one such study (172) suggest that it is not effective to present attributes entering into the contents of the orienting basis of the action being developed with the help of a real object, since they are then presented together with a large number of other properties. Conversely, the object of action should be represented by real objects for some period of time during the learning process (or else with their representations). When students deal only with drawings and models, i.e., with already abstracted objects, they may not develop a capacity for abstracting. But whether it is always necessary to combine abstract objects with real ones, in what sequence should they be presented at second stage—all these are questions that call for additional research.

As for the second (quantitative) line, its essence lies in the fact that it is by no means always true that all structural elements of an action must simultaneously be translated to the next stage: some of them are assimilated very rapidly at a given stage, while others may be delayed, and this may refer to different elements in different cases. Experiments have shown that the delay times at a particular stage for individual elements of action is determined by that element's objective complexity and the extent to which it is new to the student. A gradual approach is especially needed in effecting transitions from the second stage to the third. In cases in which we moved actions from the material stage to the external speech stage through discrete jumps a greater number of errors resulted.

In particular in the study that we have carried out together with Nikolayeva (172), which was concerned with the relative effectiveness of the material and various materialized forms of action, it was found that in all three groups ("objects-oriented", "models-oriented", and "drawings-oriented") a sharp transition to an external verbal action produced difficulties at the external verbal stage that resulted in a relatively large number of errors (Table 6).

In the first group 72 per cent of all errors were made at the external speech stage; in the second group—63 per cent, and in the third—53 per cent. It is characteristic that the greatest difficulties were experienced by the first group, where at the second stage students were concerned with real objects. The transition to a speech form was more difficult in that group than in the two others (in which students were concerned with models and drawings).

Table 6

Type of student group (10 persons in each)	Total number of errors	Stage of material (or else materialized) action	Stage of voiced speech action	Stage of unvoiced action
"Objects-oriented"	36	1	26	9
"Models-oriented"	46	11	29	6
"Drawings-oriented"	85	23	45	17
Total	167	35	100	32

In those cases in which a homogeneous system of knowledge was being developed the greatest difficulties experienced at a new stage related to initial concepts. In the study in which we were developing four elementary geometric concepts the following situation emerged (Table 7):

Table 7

Group	Number of errors made at the stage of voiced speech action	Distribution of errors among concepts			
		straight line	angle	perpendicular lines	adjacent angles
I	26	14	8	0	4
II	29	15	4	3	7
III	45	12	12	4	17
Total	100	41	24	7	28

It may be seen from the table that 41 errors out of 100 made by all the students at the stage of voiced speech action related to the concept a "straight line". Even though the next concepts, namely, "perpendicular lines" and "adjacent angles" are more complex errors at that stage were far fewer (7 in the first case and 28 in the second). Such a reduction in errors in working with subsequent concepts suggests that a transfer takes place of the speech form of the action that developed in work with the initial concept, for it has been shown that only some elements of each action are influenced by the transformations of each stage.

It may be presumed that the ease of transition from one stage to another depends on a number of conditions. In particular, the manner, in which a transition from the material stage to the external speech stage will take place, appears to depend on the relative development of the persons first and second signal systems.

With regard to the stage-by-stage development of mental actions two additional circumstances should be noted. First, depending on the type of action, the stage-by-stage formation of mental actions is applied either to an entire action or else to its orienting component alone. The latter is especially true of the development of various skills in production activities, sports and writing (e.g., 119; 128; 129; 49; 175).

Second, actions do not terminate their development upon reaching the mental stage. The stages that have been considered are stages in the emergence of new psychic action as they follow a path of internalization. But the development of mental actions and concepts is not an end in itself. (The very emergence of the psychic element in the process of phylogenesis was brought into existence by the needs of life and by a subject's relations with the world.) The mental actions and concepts that are assimilated by a subject in the process of ontogenetic development are subsequently employed in solving a variety of problems that may require that he externalize corresponding actions. In particular, we have observed many times in the course of our studies that students who confront a new problem calling for an application of actions that have already been developed begin to apply them at the external speech or else material stage.

In the course of mental development individual links in cognitive activities are still being formed and internalized while others that have developed earlier may be externalized. With regard to a person's overall mental activities it is quite possible that processes moving in opposite directions operate simultaneously. And in this respect we agree with N. A. Menchinskaya, who points to the importance of externalization in the mental development of individuals (103). But these two types of processes cannot occur simultaneously in relation to individual elements of mental activities: each element must at first be developed as an internal mental action. In addition, the relative intensity of these processes may vary in cases of spontaneous and regulated development. In particular, under existing teaching practices mental actions that have already been developed are often inadequate and formal and their externalization represents the creation of an initial form of action whose assimilation makes it possible to arrive at an adequate mental assimilation of the actions. The externalization of mental actions that have already passed through a stage-by-stage internalization, on the other hand, possesses an altogether different meaning. Unfortunately, we do not yet possess data that would make it possible to describe specific features of an externalization of mental actions of this type.

§ 5. Stages in the Assimilation of Knowledge

In the light of the theory that has been examined it is not possible to view the stages in the assimilation of knowledge separately from the stages in the assimilation of activities. For knowledge, as a set of images of objects, phenomena and actions from the material world cannot exist in the human mind outside the context of specific activities and individual actions. By emphasizing the importance of activities and analyzing activities in terms of actions we include knowledge into the structure of actions. As it appears as an object of action within its structure, or enters into the content of its orienting basis, or else represents the action's objective knowledge passes through the same stages as do actions (activities). The quality of knowledge is determined by the nature of the activity through which it is assimilated: the activity may or may not be adequate from the point of view of that knowledge. The extent to which an activity is adequate is above all determined by the object towards which the activity is directed and by the content of that activity's orienting basis. In cases in which the orienting basis includes the specific elements that constitute the essence of the knowledge being assimilated all objects with which the student will be working in the process of assimilating the given knowledge will be analyzed and will therefore be reflected in terms of those of its aspects which are essential and specific to the given area. And conversely, in cases in which the orientation on objects being studied relates to superficial properties without touching their essence, the reflection of these objects (knowledge concerning them) will also be superficial and non-specific. Knowledge may never be conveyed in a pre-established form. It is always assimilated through its inclusion into a particular activity. Even in the case of a mechanical memorization, knowledge enters into the (mnemonic) activities, which are inadequate, however, in relation to the corresponding knowledge and do not contain their essential properties and relations within orienting basis. These activities are merely oriented on their sequences in time or space.

It would be wrong to believe that the knowledge-assimilation activities are always defined to and mastered by students before such assimilation activities begin. On the contrary, in assimilating forms of knowledge that are largely new necessary cognitive actions are not yet mastered when students begin to work with the corresponding material. It would be useless to wait, for example, until mathematical thinking develops among students before they are taught mathematics, since only the process of teaching mathematics, leads to the development of mathematical thinking. As D. B. Elkonin (190) correctly observes, this is precisely the way in which the determining role of teaching expresses itself in a person's mental development.

Missing cognitive actions are modelled in an external material (or else materialized) form, in which the knowledge to be assimilated is also presented (through external objects, models, drawings). These are introduced into these actions from the very first (as objects of actions, or elements of their orienting bases). As actions move to a new stage, the form in which knowledge is presented also changes. The assimilation of knowledge and the development of appropriate systems of mental actions thus occur as a single integrated process.

For example, in developing concepts as elements of assimilation we rely on the action of associating an object with a concept. By applying that action to various objects and orienting themselves on the same system of essential attributes, students reflect all these objects from a rigorously specific point of view, i.e., produce an image of these objects corresponding to the pattern defined by a system of guidelines. In this way they assimilate simultaneously both the action of associating an object with a concept and knowledge concerning these objects.

In this connection it becomes evident why the assimilation of knowledge is always relative. First, the quality of assimilation of knowledge is determined by the extent to which the related activities are appropriate. Second, it is influenced by the extent to which its basic properties are developed, third, by the type of orienting basis that guides relevant activities, and finally, by the extent to which this knowledge is related to other types of activities.

It is important to consider this last proposition more closely. Let us assume that we are considering the development of scientific concepts.

More specifically let us consider the action of associating an object with a concept. In carrying out this action consistently at all stages, students learn to identify objects that belong to a given class instantaneously. By analyzing the objects in question in terms of their essential properties in a stage-by-stage manner they gradually develop a generalized abstract image of objects of the given class, namely, a conception of these objects. But as they successfully perform actions of recognition on such a basis they may not be able to perform other actions such as comparisons, the inference of consequences from an object's belonging to a given class, etc., since these are *other* actions which students have not been taught. At the same time they, too, may serve both as a means for developing concepts and as a learning objective. It is natural that the quality of assimilation of concepts employed in different types of activities must then be recognized as being higher than in the first case, in which the concept is bounded by a single action.

These observations clarify the nature of the developing effect of instruction. When the system of actions employed in assimilating knowledge is limited an accumulation of knowledge will take place that will not be accompanied by an acquisition of new cognition capacities. Thus, in our example the entire system of scientific concepts corresponding to a particular discipline may be developed with the help of the action of associating objects with concepts. Each time the student will be guided by the object's essential properties and will correctly recognize them. But this will be all. It is also possible to proceed in a different manner, namely, to develop the entire system of possible cognitive actions on the basis of two or three concepts. In such a case students will not acquire much knowledge, but their cognitive capacities will be substantially greater.

In programming the assimilation of knowledge it is thus important not only to employ the cognitive activities that students have already mastered, but also to gradually develop new ones. It is only then that instruction will become an effective source of development.

§ 6. The Theory of the Stage-by-Stage Development of Mental Actions in the Light of the Principles of Soviet Psychology and of the Requirements of Cybernetics

The theory of the stage-by-stage development of mental actions has emerged and developed not as a theory of instruction but as a theory of the ontogenetic formation of psychic activities. Yet since man's ontogenesis is largely a process of assimilation of mankind's accumulated experience that always requires some measure of assistance from other persons, i.e., a process of teaching and training, the given theory is that of assimilation, of learning and of teaching too.

The theory analyzes the process of learning in terms of units of action. This fully accords with the key principle of Marxist psychology concerning the need for an activities-oriented approach to the psyche.

In this theory it is concrete types of cognitive activities that are the objects of control. It views the development of activities as a process of transformation of social experience. But the corresponding transfer is effected not only through a communication of the student with carriers of social experience but through an externalization of the corresponding activity, its modelling in an external material (materialized) form, and its gradual transformation into an internal psychic activity.

The development of programmed activities initially in materialized form with control over individual operations in the course of their execution permits for all students to assimilate them in the given form. Subsequently only the form of activities is changed. It therefore retains its specified contents as it reaches the mental stage. This makes it possible to specify normative requirements relating to student cognitive activities.

By identifying actions as the central link in the control of the process of developing cognitive activities the theory under consideration points to the structure of actions and to their functional components. Above all it points to those structural elements and those functional components that play a decisive role. The results of studies indicate that regulation should be primarily directed at orienting components.

This theory also describes a system of independent characteristics of cognitive activity which is needed both for programming the specifications of particular types of cognitive activity and for regulating the process through which they develop. It is these characteristics that define the content of feedback. Finally, this theory possesses a knowledge of major transition states in the process of assimilation of new types of cognitive activities. It is true that qualitative transitions are not yet known for all independent characteristics, but it is already possible to programme activities in terms of their form, scope of generalization, and rate of execution.

The theory under consideration thus meets the principal requirements that were identified as being necessary for an effective control of the learning process.

§ 7. Basic Principles and Stages in Programming the Assimilation Process

1. No matter what a person may be learning it is always activity or else its component actions that are subject to control. Activities (actions) are thus the concrete control *objects*.

2. The *objective* of control may be: a) to develop a new type of activity possessing specified qualities: b) to improve the quality of existing activities in terms of one or more of their characteristics; c) to develop individual elements of particular activities to meet specified indicators. Thus, any instructional process must begin with the selection of an activity (concrete object of control) and an indication of the objective of control (of teaching). The selection of a specific type of activity is determined by the

specific properties of the problems for whose solution the teaching process is organized.[1] The principle that instruction must be related to practice requires that the knowledge developed by students and the types of cognitive activities that they mastered contribute to the solution of problems that arise in practice.

3. The selection of a type of the orienting basis for programmed activities (actions). This may be the second, third, or fourth type: other types are not able to provide an effective regulation of the assimilation of activities.

4. The presentation of the activity being developed (or else new elements of such an activity) in a material or else materialized form. Preceding modelling of actions (activities) presupposes that: a) the object to which the action will be directed is specified (through a selection of problems); b) that the objectives of the action (the outcome of actions) be clearly understood; c) that the content of the orienting basis of action be indicated; d) that the entire set of operations entering into the action and the sequence in which they are to be executed be indicated. This may be called a set of instructions for carrying out the action.[2]

5. The selection of problems on the programmed activity in the light of the instructional objectives (form, degree of generalization, rapidity, etc.) and of stages of assimilation. In particular, in order to generalize the specific (object-oriented) part of the activity problems are selected that reflect the basic typical cases, while in order to generalize the logical part, typical logical situations are selected. In order to arrive at the specified form of activity, problems that have been selected are presented both in the given form and in all genetically preceding forms. In order to bring about an automation and reduction in activities so as to make them more rapid, a sufficient number of uniform problems are selected (variants of typical problems). Each

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[1] These tasks are usually not specified in current teaching practice. Instead the teacher usually accepts such objectives as: to provide reliable knowledge, to teach creative applications of knowledge, etc. This largely explains why students merely memorize much of the corresponding knowledge without applying it to the solution of problems.

[2] Such instructions are often called algorithms of the given action, even though this does not always conform to the meaning of that term. A detailed analysis of various types of instructions, including algorithms, is presented in L. N. Landa's work (81).

assignment should be concerned with developing specific action or else with its joint application with other earlier developed actions. The scope and complexity of problems may thus vary at different stages of the teaching process.

6. The selection of check tests intended to establish the extent to which the developed activity corresponds to the one that was assigned in terms of a) content; b) form; c) scope of generalization; d) extent of assimilation; e) extent of awareness; f) rationality; g) resilience. Depending on the instructional objective either all properties or only some of them are controlled.

The level (form) of action is established with the help of a presentation of problems concerned with the application of the given action (activity) for different forms (material or verbal) of specification of its structural elements (object, orienting basis of action, operations, etc.). The process of arriving at a solution then proceeds either in a material (materialized) form, or else in an external speech form, or in the form of unvoiced internal speech. An ability to solve a problem calling for applying the form of action being controlled indicates that the given level of action has in fact been developed.

The extent of generalization of actions is established through assignments involving their "transfer" to other situations. A capacity to effect such transfers is verified both in relation to the action as a whole and in relation to its individual components. Thus, for example, the action of overall recognition reveals generalization only within the boundaries of the particular concept that was developed through work with its attributes. Its general logical component possesses an altogether different level of generalization and may be transferred to any other concepts possessing the same logical structure of attributes. This is established in the following way: a new concept's system of necessary and sufficient attributes is given to students in a materialized form, and they are taught to identify the presence of individual attributes of that concept in concrete objects. Subsequently, they are given problems in associating objects with the new concept. Since they are not given either logical rules of recognition or instructions for solving problems of the given class a correct solution of all basic types of new problems is possible only if the logical part of the action that was developed in relation to earlier concepts is transferred to the new situations. This in turn reflects the measure of generalization of that particular action component.

Indicators of the extent to which an action is assimilated include: a) the rapidity of execution; b) the ability of combining the given action with the execution of another that is not automated: this makes it possible to judge the extent to which the first is in fact automated.

The theory under consideration does not possess reliable diagnostic means for establishing the extent to which actions are reduced. Up to a certain point this may be indicated by the rapidity with which it is executed, but that indicator reflects not only reduction but other changes in the action as well, and especially the extent to which it is automated.

In order to ascertain the rationality of actions problems are given whose conditions are not fully specified and for which the answer is accordingly uncertain. Problems of this type may be solved only through an orientation on the entire system of essential conditions, i.e., through a reasonable execution of actions.

An indicator of the extent to which the actions' assimilation is a conscious act is provided by the ability of students to justify actions.

The resilience of actions and of their qualities is established through repeated diagnoses after a specified period of time (without additional teaching) either in relation to all specified indicators or to only some of them.

7. Ascertaining the required initial level of student cognitive activity. From the point of view of the theory under consideration the initial level of student cognitive activity is evaluated in several dimensions corresponding to the structure and functional components of the programmed activity. First, in terms of a knowledge (mathematical, grammatical, physical, etc.) that logically precedes the new knowledge entering into the instructional goal or else the content of the orienting basis of proposed activities.

For example, if the instructional objective envisages the development of a particular system of concepts, it is necessary to verify whether students have already assimilated other concepts that constitute a system of prerequisite types of knowledge. Let us assume that it is proposed to develop the concept of a perpendicular line. This is possible only if students have already assimilated the concept of a straight line, the concept of an angle and have some conception concerning types of angles (acute, right, obtuse). Each of these types of knowledge enters into the content of the orienting basis of action relating to the development of the concept "perpendicular line".

Second, it is necessary to verify the extent to which the action that is proposed to employ is in fact developed. If it is a new action and has not been developed it is necessary to verify the extent to which those cognitive actions that logically precede it are developed. Thus, for example, if in order to develop new concepts it is proposed to employ the action of associating an object with a concept, students must be already able to identify properties in objects and differentiate the essential ones from nonessential ones, and the necessary ones from the sufficient ones.

In cases when students have not yet mastered the necessary knowledge and actions they have to develop them either preliminarily or else, in individual cases, jointly with the development of new knowledge and actions.

In order that new knowledge and actions may develop successfully it is important to also verify the extent to which systems of less specialized skills and knowledge are developed. If, for example, the student had not developed the required level of attentiveness (a control activity) he will not be able to reach successfully even the stage of constructing a representation of the orienting basis of action (the first stage), since he will not be able to follow the explanation that is being given at that stage and understand it, and therefore will not be able to develop an adequate conception of the new action. The given stage of development of action will not reach its objective, and without this a transition to the next stage will not be effective. Similarly, if students are not able to initiate work on the basis of written instructions while the teaching programme calls for this, then this, too, must be taught either on the basis of the given materials or of others.

8. A teaching programme is designed on the basis of a model of the corresponding activity and a selected system of problems. Such a programme includes: a) a programme for developing prerequisite cognitive actions and knowledge (a preliminary teaching programme) and b) a programme

for developing new activities that follow from the teaching objective (the principal teaching programme).

The principal teaching programme is designed with due consideration of the stages of assimilation: the newly programmed activity must pass through all genetically earlier stages than specified by the teaching objective. Taken in its entirety the teaching programme constitutes a system of problems that presume the execution of the programmed activity and the development of envisaged properties of such activities. The problems themselves are viewed jointly with activities: the conditions specified in the problem appear as objects towards which activity is directed, while those that are sought appear as the objectives that should be reached as a result of executing these actions. Instructions relating to the execution of activities appear as indications of the manner in which the object should be transformed and the objective achieved. The defined properties of the activities are achieved both through the selection of problems and through the corresponding structure of activities. Thus, for example, the state of generalization of activities and of knowledge that they incorporate is achieved by fulfilling the following conditions: 1) an identification of the attributes in relation to which generalization should take place; 2) the inclusion of these attributes into the orienting basis of action; 3) the presentation in the system of problems of typical situations occurring within the given boundaries of generalizations; 4) the presentation of various types of problems from the point of view of comprehensiveness of the conditions needed for a solution.

9. Providing for a systematic feedback. In accordance with the objective of control feedback must carry the following information: a) whether the student executes the particular action that has been programmed; b) whether he executes it correctly; c) whether the form of action corresponds to the given stage of assimilation; d) whether the action is developed with the desired level of generalization and assimilation (degree of automation, rapidity of execution, etc.).

Control activities must relate both to individual operations and to the action as a whole. Control over individual operations makes it possible to obtain information about the extent to which the execution of actions is adequate, correct, rapid, and about their forms. Information of this type cannot be obtained in cases in which control activities relate only to the correctness of the final outcome of the action, since both the content of the action and its form are not associated with the correctness of the execution of the problem through mutually unique relations. As a result errors in the final outcome do not point directly to an appropriate correcting action: errors may be attributable to a variety of causes (whether the action that had been executed possesses the right content, whether all operations were included, whether it took place in the proper form, etc.)

Systematic control activities in terms of operations, however, should be carried out only at the beginning of the material (materialized) stage and at the beginning of the external speech stage. At other stages of the assimilation process the feedback relation that carries information to the student (internal feedback) must operate in such a way as to reflect the objective degree of success in carrying out the programmed activity and the need of students for external forms of control.[1]

Control over the content of an action and over its form may be effected as assignments are carried out. Special diagnostic problems such as those mentioned earlier must be employed in order to establish the extent to which activities have been generalized and automated. As a result the corresponding control activities are not carried out systematically: they usually take place at the time of transitions from one stage to another, sometimes within a given stage, and of course, are mandatory at the conclusive stage of the learning process.

In the light of what has been stated it is clear that in the absence of feedback relations a teaching step, viewed as a segment of activity, does not possess a specific dimension. Initially the "step" corresponds to a single operation within the action, but later its size increases.

In shifting to the next stage progress is again measured in terms of operations. At the mental stage actions are carried out discretely without visible division into individual operations.

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[1] From the methodological and technical points of view feedback relations may be effected in various ways. Wide use may be made of various automatic devices. In addition, a considerable number of control procedures have been developed that do not require machines (see, for example, the article of Z. A. Reshetova and I. P. Kaloshina [132] and the study by N. F. Talyzina [168, Chapter III] and others).

10. Regulating the assimilation process. The direction of the corrections that are entered is determined by the nature of the information, received with the help of feedback and by the internal logic of the assimilation process.

From the point of view of the conception that we have adopted the nature of assimilation is expressed in the logic of the transformation operations carried out by students: actions that are initially external, material, extensive, and non-automated become internal, mental, reduced, and automated. Each characteristic of an action possesses its own transformational logic, and each of them passes through a number of phases.

The correction of the assimilation process must be carried out with due consideration not only of the extent of deviation but also of the causes that have brought it about. These include: a) deficiencies in the initial level of the student's cognitive activities; b) an insufficient mastering of actions in terms of one or several parameters at a preceding stage of assimilation; c) accidental factors (distractions, errors in reading a text, etc.).

In the first case a further development of earlier knowledge and actions is required; in the second a return of the action is needed to the preceding stage in terms of one or more characteristics; while the third calls for a repeated execution of the action at the given stage.

Experimental studies show that in those cases in which students have developed the necessary initial level of cognitive activity and have carried out all major specifications following from the theory of a stage-by-stage assimilation of mental actions deviations from a course specified in the teaching programme occur for accidental reasons, and primarily as a result of distractions.

As has already been noted the regulation (correction) of the assimilation process may also take place in those cases in which there are no deviations of the process from the specified course. This is because the number of problems that is needed to assimilate a programmed action possessing a specified system of characteristics is determined in an empirical manner, that is, in the course of preliminary tests of the teaching programme. This may result in cases in which the number of problems included in the teaching programme is too large for some of the students. Such students should be transferred to the next stage earlier than had been anticipated. The possibility of an earlier transfer is determined, first, on the basis of the quality of the tasks that have been performed, and second, by proposing to the student to execute the problem in a form corresponding to the next stage. Should the student succeed in doing this without difficulties he will be transferred to the next stage.

Newly designed teaching programmes usually pass through the following stages of approbation: a) for individual students; b) for small groups; c) in conventional teaching conditions.

When a teaching programme is designed to help assimilate an entire discipline rather than develop an individual type of cognitive activity, as in the described case, a number of additional problems arise, and some of the principles mentioned earlier require a partial revision. Above all, the entire system of problems that are encompassed by the given discipline is analyzed. Possibilities are studied for combining them into a system (or systems) and for identifying invariants within that system (or subsystem). If this is achieved then a fundamental reconstruction of the discipline is carried out in which it is restructured in accordance with the third type of orientation and in terms of modelling general methods that correspond to the system's invariant (or else the subsystems' invariants). In developing individual types of activities the bringing of their properties to given specifications is effected gradually. Let us assume that at the end of the teaching process the action must be brought to the mental level, but the analysis of the overall system of actions indicates that the given action appears as a component element in another action. In such a case the assimilation of the first action may only be carried to the material form. It is in that form that it may then be included into the new action, whose execution will bring about its transformation into a mental form.

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Analytical studies show that the conception that we have been considering opens possibilities for programming rational types of cognitive activities, and above all of procedures for logical and specific thinking.

But an implementation of such an approach to a programming of the assimilation process presupposes a preliminary identification for each discipline under study of a system of specific and logical thinking procedures as well as an indication of rational types of overall cognitive activities. It is only then that it is possible to construct a teaching programme that is directed at developing specified types of cognitive activity, and through them, those types of knowledge that constitute the content of a given discipline.

A large number of experimental studies have been carried out on the basis of that theory. They were applied to different subjects (mathematics, language, history, physics, chemistry, technical disciplines) and to various levels of education (preschool-age children, students in various grades, post-secondary-school students). In all cases in which the specified requirements pertaining to the design of teaching programmes were carried out the envisaged types of cognitive activities were developed among all students and with those characteristics that had been planned.

We have carried out a series of studies relating to the development of mental actions relating to the assimilation of concepts as well as to developing a number of thinking procedures. Let us now consider these studies in order to illustrate the specific ways in which that theory was applied and to examine the results that were obtained.

Chapter Three

THE DEVELOPMENT OF INDIVIDUAL MENTAL ACTIONS AND OF SCIENTIFIC CONCEPTS

§ 1. Development and Study of Elementary Scientific Concepts

It was L. S. Vygotsky who first introduced the distinction between scientific and nonscientific "worldly" concepts in the field of psychology drawing the line between them rather by the *specific features of their assimilation* than by the content of the assimilated concepts.

A child's assimilation of systems of concepts that have developed in a society always takes place with the help of adults. Before children are taught systematically in school adults are not engaged in specialized activities on developing concepts in children. They usually limit themselves to indicating that the child was either correct or wrong in associating an object with a corresponding concept. As a result a child assimilates concepts through the method of "trial and error". This sometimes produces an actual orientation in terms of nonessential attributes, but because the latter are combined with essential ones within the corresponding object the orientation remains correct to a certain extent. In other cases the orientation is based on unconscious identification of essential attributes. It is precisely in this unconscious identification that Vygotsky saw the specific features of so-called worldly concepts. This type of assimilation of concepts does not reflect all aspects of the specifically human method of acquiring new knowledge.

The situation is altogether different when a child enters school. The process of learning presupposes a transition from a spontaneous course of activities to activities that are goal-oriented and organized. Concepts that are developed in children at school are characterized in Vygotsky's opinion by the fact that their assimilation begins with an awareness of a concept's essential attributes, which is achieved with the help of definitions.

It is precisely in the *awareness* of essential attributes that Vygotsky saw the specific way of developing scientific concepts. He referred to the development of concepts that began with an identification of essential attributes as an approach "from above", i.e., from definitions to real objects, unlike approaches "from below", from objects to definitions, which characterizes the development of "worldly" concepts.

Vygotsky saw the advantages in the development of scientific concepts "from above" in that such an approach makes it possible for the child to subsequently operate with concepts autonomously and consciously. In support of such a view he referred to the experimental studies of J. I. Schiff, in which a child was asked either to provide a definition of a concept (for example, he was asked "What is a revolution?"), or else was asked to complete a sentence ending in "because" or else "even though" ("In the USSR it is possible to manage the economy in accordance with a plan because...") (25, Chapter Six). Yet such problems may be solved with the help of a recitation of a memorized text, or else of the teacher's words. They do not require an autonomous identification of essential attributes of concepts. Accordingly, data from such studies do not prove that essential attributes of concepts assimilated in school may be employed by children consciously and autonomously in their orientation within the surrounding world.

Studies subsequently carried out by Menchinskaya and her associates (100) have shown that in identifying concrete objects calling for the application of concepts assimilated in school most students rely on nonessential attributes. Thus in geometry, for example, they orient themselves on the position of a figure, and in grammar on the contents of words. Essential attributes of concepts are perceived and reproduced only in replying to questions that require definitions of concepts. This indicates that in such cases knowledge possesses a verbal, formal character.

While students repeat definitions of concepts without error, i.e., display knowledge of their essential attributes, they identify real objects by random attributes, on the basis of direct experience. It is only gradually, through a number of transition stages and as a result of their own experience with corresponding objects that students learn to orient themselves on essential attributes of objects. Thus, a verbal knowledge of a concept's definition does not change the essence of the process through which that concept is assimilated. This confirms the impossibility of conveying concepts in a prespecified form. Children may acquire them only through their own activities directed not at the words but at the objects that correspond to the concepts that we wish to develop. Vygotsky emphasizes the point that it is necessary for a child to engage in a specific object-oriented activity in order to assimilate concepts. Moreover, he shows that a given result obtained through different mental activities is associated with different stages in concept formation (25).

In Vygotsky's analysis of the course of concept development, however, cognitive activities appear neither as an object calling for special development nor as an object of study. As a result he views the development of so-called worldly concepts and that of scientific concepts as two fundamentally different ways. From the point of view of a child's activities both are not controllable or else poorly controlled, and both are unknown to the learner. In order to alter such a development of cognitive activity or to overcome its spontaneous character it is not sufficient to simply state a concept's essential characteristics. For a knowledge of a concept's essential characteristics may alter the nature of these activities and their course only when these attributes operate as guidelines for the activities, i.e., participate effectively in the process of solving the problems that are given to the child.

Since the usual forms of organizing teaching and learning processes do not provide for this, for many students the assimilation of "worldly" concepts and of scientific concepts from the viewpoint of their cognition proceeds in a largely similar manner. Above all, under prevailing teaching practice many students assimilate concepts at the same level as they assimilate "worldly" concepts: in effect they rely on essential attributes, but frequently they are not aware of doing this and are unable to rely on them in a goal-oriented manner in solving problems. In particular, studies that we have carried out jointly with K. A. Stepanova (174) show that in solving problems relating to the association of elementary geometric concepts with objects average sixth-grade students answered 72.5 per cent of the questions correctly, but gave a correct explanation of their selection in only 27.5 per cent of the cases. In the study carried out by

V. I. Zykova (66) it is noted that such a level of assimilation of concepts is found up to the eighth-ninth grades. Thus, a knowledge of essential attributes does not produce an ability to employ them consciously in orienting one's self in the corresponding situations. It is therefore not possible to agree with Vygotsky that a simple memorization of essential attributes provides a fundamentally new approach to the assimilation of scientific concepts.

The considerable emphasis that is found in teaching practice on the memorization of definitions and rules is explained by an incorrect understanding of the process of assimilation: it is often believed that a concept existing in an already established form may be transplanted into the minds of students.

Vygotsky opposed such a view of the assimilation of concepts but in carrying out and analyzing concrete studies he found himself a captive of that intellectualistic theory. This is precisely why he thought "verbalism" appropriate for assimilating scientific concepts and viewed them as inappropriate for the practical orientation of students. By omitting the subject's *actions* in his analysis of the process of assimilation Vygotsky failed to identify individual systems of concepts as *products of man's concrete activities* directed at those objects and phenomena whose essential aspects are reflected in the corresponding concepts.

When the activity that is needed to assimilate concepts is not identified and organized before the beginning of systematic teaching the task of teaching is precisely to identify it and to organize it in a comprehensive manner. Since Vygotsky did not view a subject's activity in relations to the objects as a decisive link in the process of assimilating concepts he did not see that the cognitive activities of schoolchildren are largely unorganized, spontaneous. As a result, instruction in schools does not generally provide a fundamentally new way of assimilation and hence a fundamentally new way of development, since, as L. S. Vygotsky correctly observed, it is instruction that determines a person's course of development.

If we turn to other studies concerned with the development and evolution of concepts we will see that most psychological studies have two significant shortcomings: a) the activities leading to the development of concepts are not studied and, in fact, are not considered; b) the assimilation of concepts is studied in the context of conditions under which the development of that activity is not organized.

As a result, the principles that are identified are of limited relevance and reflect characteristics of concept development in conditions in which cognitive activities largely proceed in an unorganized way. They should not be interpreted as reflecting the specifically human way of transferring and assimilation of social experience.

On the basis of numerous studies of this type (100; 101; 125; 114; 13) the development of concepts is presented as a gradual movement from an orientation on isolated external and random object attributes to an orientation on a system of essential attributes characterizing their essence. Such a description of the process of assimilation of concepts cannot be accepted as satisfactory. First, we do not obtain a positive characterization of the course of the process but only learn about deviations from such a course. Second, descriptions of deviations relate only to the content of concepts analyzed from the point of view of the extent to which they are essential and comprehensive and also of relationships between the content of the concepts and their scope. These are aspects of the process of assimilation of concepts that are logical rather than psychological.

These studies view the specific features of developed concepts as a direct outcome of the influence of particular objects on the subject. This suggests that the only way in which the process of assimilation of concepts may be influenced is to control the selection and organization of the materials that are presented to students.

In theory such an approach to investigation of concept formation confirms the view that concepts are developed through the influence of the external world on a passively perceiving subject. Yet those studies have also shown that not all students, and not always, assimilate concepts through a series of errors. This alone provides grounds for concluding that the view on the process of assimilation of concepts as merely a movement from one set of errors to another does not reflect its psychological nature and may not be accepted as adequate even in cases in which cognitive activities proceed in an unorganized manner.

Nor is it possible to agree with the method that is usually applied to define the stages through which concepts are assimilated: according to this view the capacities of students of different age groups and different abilities are established with the help of logical methods (the "cross section" method) and types of deviations from these capacities are then monitored and ranked in terms of the decreasing seriousness of the corresponding errors. It is that sequence of errors that then defines the series of stages that are presumed to follow each other in the process of assimilation.[1]

In our view it is impossible to identify genuine stages in the concept formation without identifying the system of essential psychological characteristics of the process of assimilation which makes it possible to describe its different states, and without applying the genetic method, which makes it possible to follow that process from beginning to end in relation to the participants.

Basing ourselves on an understanding of the psyche as an activity we inevitably come to the conclusion that any image, whether it is a perception, an image or a concept, must be associated with a specific system of actions. Accordingly, the concept formation is not only a process in which a particular image is formed as a picture of the world, but also a specific operational system possessing its own internal structure. It is actions and operations that constitute the specifically psychological mechanism of concepts. Actions operate as a means of the development of concepts and as a mode of their existence: outside of actions, concepts can neither be assimilated nor subsequently applied to the solution of problems. As a result, the specific characteristics that attach to the development of concepts cannot be understood without considering the activities whose outcome they represent.

The specific features of actions directed at objects and phenomena of the external world determine directly the content and quality of the concept being developed. Of course, a concept is always an image of some objects and phenomena from the objective world. But these objects and phenomena possess an infinite multitude of different properties and different aspects, and which of them will enter into the content of an image is determined not by the object itself but by the nature of the interaction between the subject and that object. A decisive role is played by those aspects of an object towards which a person's actions are directed, and also by the reference pattern in accordance with which an image is copied from that object, as it were.

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[1] A critical analysis of the "cross section" method has been described in an article by P. Ya. Galperin (41).

It is above all in the following respect that our own approach to the study of the process of concept development differs from the one described above: we analyze that process from the point of view of activities and actions associated with the development and operation of concepts. In addition, we trace the formation of actions associated with concepts in the context of comprehensive forms of control over the course of their development, rather than outside the context of organized conditions.

§ 2. Actions Underlying Concepts

"...An action is a process, while an image is something that is instantaneous and static; in an image the object countervails the action; the former confronts the action. But on the other hand, images reflect the objects in relation to which actions are carried out, and that reflection is formed on the basis of actions in relation to objects" (36, p. 463).

Since each image is associated with a specific system of actions, our first task is to identify these actions. In order to identify them it is necessary to analyze the problems whose solution requires that concepts be developed. Of course, each scientific discipline possesses its own specific characteristics in this regard. Nevertheless, in a general sense the objective of developing most scientific concepts is to teach persons to orient themselves with the help of these concepts in corresponding areas of activities: to recognize phenomena, compare them and discern properties that are characteristic for objects of the given class.

In working primarily with elementary geometric concepts we have established that their assimilation presupposes the development of at least three actions that are not specific to these concepts, but are required for work with any concepts. Among the first to be identified was the action of associating an object with a concept. This includes two parts: a) a general logical part and b) a specific part. The general logical part includes, above all, the general structure of identification determined by the structure of attributes of the concept (conjunctive, disjunctive, mixed), while the specific part refers to operations in identifying within objects those attributes that are necessary and sufficient for associating (or else not associating) them with the given concept. Later in a study carried out by M. B. Volovich two additional actions of this type were identified: the action of selecting a system of necessary and sufficient attributes to identify the object; and the action of inference (18; 19).

The action of inference is the inverse of associating an object with a concept. In associating an object with a concept the problem is to establish whether the given object is associated with a specified concept. We achieve this by establishing the presence in the object of a specific system of properties (attributes), and on that basis we conclude whether or not the given object does belong to the given concept. Conversely, in inferring, it is known from the first that the object belongs to the given concept, and that the problem is to indicate those properties of the object that it must possess, i.e., properties that are a result of the object's belonging to a given class of objects (to a given concept). That action is itself as general as is the action of associating an object with a concept. A concept may not be viewed as fully developed if the person possessing it is unable to carry out actions of inference that presuppose an assimilation of the entire system of essential properties of the objects of a given class and not only of those that are sufficient for identifying these objects. These two actions make it possible to convey to students the difference between necessary properties with which the action of inference is associated and necessary and sufficient properties on which the action of associating an object with a concept is based.

The action of selecting, on the other hand, is less general than the first two actions. In a number of cases that action precedes the action of associating an object with a concept. This is because it is possible to recognize an object as belonging to a given class without relying each time on the same set of properties. In many cases several such equivalent systems may be identified. (An example from geometry concerns the attributes of the equality of two triangles. Each of them is sufficient for establishing the equality of two triangles.) That action makes it possible to understand relations among different properties of a concept and their mutual substitutability in particular circumstances.

Each of these actions presupposes an assimilation of specific components entering into that action as operations and directed at essential properties of the object; these properties are specific in each scientific discipline and are established with the help of methods and procedures that are specific to the given discipline. These are the actions that must be made the objects of a special assimilation. At the same time they will appear as means for developing concepts representing a specific outcome in the form of generalized knowledge.

Naturally, these actions do not represent the entire system of actions associated with scientific concepts. General logical actions also include the actions of comparing, classifying, and actions associated with the establishment of hierarchical relations within a system of concepts (genus-species), etc. The order in which logical actions are to be performed is determined both by their contents and by relations among them.

§ 3. Control of Actions and Concepts Assimilation Process

A person may acquire a new concept only through a contact with those objects to which the concept refers. In order to control that process it is necessary, from the very first, to organize actions that are directed at those aspects of the objects that interest us. In such a context students should be given guidelines (standards) in accordance with which they will "copy" images from objects. Of the actions associated with the development of concepts that we have noted the association of objects with concepts meets these requirements best.

Thus, *the first condition for control* of the process of assimilating concepts (knowledge) is the existence of an action that is appropriate to the specified objective. An action is appropriate only when it is directed at properties that represent the immediate object of assimilation.

The *second condition for such control* is a knowledge of the structural and functional composition of the action that has been identified. The actions that we are considering include identifying the presence (or absence) of each attribute from a system of necessary and sufficient attributes and evaluating the corresponding results. Such an evaluation (for concepts possessing a conjunctive structure of attributes) is carried out in accordance with the following logical rule: if all necessary and sufficient attributes are present, then the object matches the corresponding concept, while if even a single attribute is missing, it does not belong to the concept; if nothing is stated concerning even a single attribute, then even if all remaining attributes are present a conclusive answer cannot be given.

It is on that basis that an instruction—an "algorithm"—for recognition is designed: 1) name the first attribute; 2) establish whether the object possesses the first attribute [1]; 3) record the outcome; 4) verify the correctness of the answer. If the answer is correct the student is then asked to repeat the same operation in relation to all the attributes listed as necessary and sufficient. If the student has made an error he is asked to verify whether the object does possess the attribute in question. If that does not help the cause of the error is identified, and a corresponding restructuring of the process takes place through the completing of prerequisite actions and a return to the preceding stage. Following the verification of the entire system of attributes the student is asked to compare the findings with the rule, and then to write down the answer. Particular emphasis is given to the orienting basis of action which must be comprehensive as well as adequate.

That condition was not met in our earlier studies (164; 50): the logical rule of recognition was not introduced into the orienting basis of the action relating to associating an object with a concept. Instead only a system of necessary and sufficient concept attributes was introduced. As a result, students were not safeguarded from errors, which occurred most frequently in carrying out the action under difficult situations—in solving problems with not fully specified conditions.

We became aware of the need to expand the orienting basis of the action of associating an object with a concept in the course of experiments. In principle, this could have been established in a purely logical way as well.

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[1] Naturally, students are taught how to establish the presence or absence of specific attributes, and this initially appears as an independent action and only later becomes a component of the action of recognition and thus an operation.

The *third condition for control* is the representation of all elements of action in an external, material (or else materialized) form. In relation to the action of associating an object with a concept this appears as follows. A system of necessary and sufficient attributes for the given concept is listed on a card and these attributes are materialized. (For example, in assimilating the concept "perpendicular lines" models of straight lines and of right angles are given.) The logical rule of action is also materialized; the following type of conventional representation is given[1].

$$\text{I.}\ \left.\begin{array}{l}1+\\ 2+\end{array}\right|\,+ \qquad \text{II.}\ \left.\begin{array}{l}1+\ (?)\\ 2-\end{array}\right|\,- \qquad \text{III.}\ \left.\begin{array}{l}1+\ (?)\\ 2?\end{array}\right|\,?$$

It is explained to the students that a plus following an Arabic number stands for the presence of the corresponding attribute while a minus stands for its absence, a question mark means that this is unknown (it is impossible to provide a definite answer). A plus after the vertical bar means that the object being defined matches the corresponding concept and a minus that it does not, while a question mark means that it is unknown whether it does match it or not. In addition, it is indicated that in the second and third cases the answer does not change when a minus and a question mark relate not to the second but to the first attribute. The recognition algorithm is also written down on a card.

The objects of action are represented either in the form of objects from the environment or as geometric models, drawings and diagrams. They include objects that do not match the given concepts.

The *fourth condition* is a stage-by-stage development of the action that has been identified with an adequate processing of all given parameters.

In the case of actions relating to the association of objects with concepts, they were carried out in the following way. At the stage of preliminary acquaintance with the action (the first stage) following the creation of a problem situation students are told the purpose that is served by the action of associating an object with a concept, and the importance of verifying the entire system of necessary and sufficient attributes as well as the possibility of arriving at different results. All this is illustrated in terms of specific situations in a materialized form. Subsequently students are asked to carry out that action by themselves. That is the second, materialized stage.

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[1] Of course, the system may include either more or less attributes than those that are necessary and sufficient.

Relying on the guiding elements presented in a material or else materialized form, students establish the presence of the necessary system of object attributes, specified either directly or else in the form of models and drawings. The outcomes of each operation are recorded with the help of the conventional signs (+, —, —?). After carrying out five to eight assignments the students remember without any memorization both the concept's attributes and the rule of action. Then the action is translated into an external verbal form (the third stage), when assignments are given in written form and the concepts' attributes as well as the rule and instruction are either stated or else written by the students from memory. At this stage students are free to work in pairs and assume in turn the function of either execution or control.

Once the action is carried out easily and accurately in an external verbal form it may then be moved on into the stage of "unvoiced external verbal form". The assignment is given in written form and the specification of attributes as well as their verification and comparison of outcomes with the corresponding rule are carried out in an unvoiced form. Students are still given such instructions as "State to yourself the first attribute", "Check to see whether it is present", etc. Initially the correctness of each operation and of each final answer is controlled, but gradually control activities relate to the final outcome alone and are carried out when necessary.

If the action is carried out correctly it is moved on to the fifth or mental stage: the student then carries out and controls the action by himself. At this stage the teaching programme provides for external control of the student only with regard to the final outcome of actions; the student receives feedback in the presence of difficulties or uncertainty concerning the correctness of the outcome. The process of execution is now hidden from view, the action has become fully mental and ideal, but its content is known to the teacher, since he designed it and also produced its transformation from an external, material action.

This, then, is the way in which actions are transformed in relation to their basic parameter, namely form. Transformations of actions in relation to the parameter of generalization are provided by a special selection of assignments. Naturally, the boundaries of generalization are specified in advance. In order to arrive at a specified level of generalization typical problems are presented within specified boundaries. These also take into consideration the nature of the specific as well as of the general logical part of the orienting basis of action.

In order to generalize the specific part that is associated with the application of a system of necessary and sufficient attributes all representative types of objects belonging to the given concept are presented. Thus, while developing the concept of an angle it is important that the student operate with angles that differ in size (ranging from zero to 360 degrees and more) and in their position in space. It is also important to consider objects that possess only some of the attributes of the given concept but do not belong to it.

In order to generalize the logical part of the action of recognition all basic cases provided for by the logical rule of associating an object with a concept are given, i.e., assignments with positive, negative and uncertain answers. In a number of our studies we also introduced assignments with excessive specifications. It is characteristic that in the usual teaching practice only one type of problem is given: one possessing a sufficient set of specifications and for which there is a positive answer. As a result, students assimilate the action of associating an object with a concept in an insufficiently general form, and this naturally limits the range of applications. Problems possessing excessive and inadequate specifications make it possible to teach students not only to find particular attributes within objects, but also to establish their sufficiency for solving a given problem. In practical situations this often appears as an independent problem.

The transformation of an action along two other parameters is achieved through a repetition of assignments of a particular type. As has been noted this is desirable only at the last stages, the fourth and the fifth. At all other stages the number of assignments that is given is determined by the needs for assimilating the action in the given form, i.e., by a confident execution of all operations, together with substantiation of each of them and with a specified level of generalization. Actions should not be held up at transitional stages since this will produce its automation in a given form, and it has been observed that this inhibits the transition of the action to a new, genetically more developed form.

The *fifth condition for controlling* the process of assimilation of concepts concerns the presence of an operation-by-operation control in assimilating new forms of actions. It has already been noted that control in relation to the final outcome of the action alone does not make it possible to follow the content and form of the actions executed by the students. Control activities relating to individual operations provide for information concerning both. In the development of concepts with the help of the action of associating objects with concepts the relevant operations include a verification of each attribute, a comparison with the logical rule, etc.

Naturally, before developing the action of associating an object with a concept it is necessary to establish the initial level of cognitive activities of the students, and to carry out the development of necessary prerequisite knowledge and actions. (The nature of the knowledge and actions that are required for developing this particular action were mentioned in Paragraph 7, Chapter Two.)

§ 4. Specific Features in Assimilating the Action of Associating an Object with a Concept That Bear on the Quality of Newly Developed Concepts

The principal experimental material that we have employed in our studies related to concepts of elementary geometry. Students were usually fifth-grade schoolchildren of average or else less than average performance who had not yet studied geometry. Some students participating in the experiments were drawn from the fourth grade. They also included sixth-grade schoolchildren whose achievements in this field of geometry were inadequate. In most experimental studies the development of concepts was carried out on an individual basis.

1. The Assimilation 'Process in Conditions of Expertmental and Conventional Teaching

In the studies that we carried out or were carried out under our direction elementary geometric concepts were developed in approximately 400 fourth-, fifth-, and sixth-grade students through an application of the above-mentioned principles.

A special test has shown that when a regulation regime is applied the development of concepts occurs almost without errors. It may be stated with complete confidence that the view that assimilation represents a gradual emancipation from errors does not correspond to the actual nature of that process. The path leading from an absence of knowledge to knowledge is characterized not by a replacement of some errors by others—in principle that path may produce no errors—but by a replacement of the forms in which that knowledge exists, which differ in terms of their level of generalization, reduction, etc. It is in qualitative changes in form and in transformations of knowledge and actions in terms of a number of characteristics that the true nature of the assimilation process expresses itself.

If we turn to the conditions of instructions in the schools we find that both the students in experimental groups and other students are often confronted with problems of recognition of corresponding phenomena and objects. They are required to perform the action of associating an object with a concept. In a school environment, however, that action is not developed as an object of special assimilation—the students must perform it themselves. They usually receive only a system of attributes that are necessary and sufficient for the given concept (through a definition), i.e., the content of the specific part of the orienting basis of action of associating an object with a concept. But since the system of attributes is given not within the action's structure but independently students find it necessary to enter it into the orienting basis of action by themselves, and it is at this point that many of them fail. As a result, the definition of the concept, which such students are able to reproduce correctly, "will be ineffective". In addition under conditions of conventional instruction students are not always taught methods for identifying essential attributes in concrete problem situations.

This leads to the development of an orienting basis of the given action through "trial and error". Since the orienting basis of action is relatively complex, a large number of trials are needed, and hence a large number of errors are produced. If we analyze the nature of the errors we will see that at first students gradually identify the specific part of the orienting basis of action. They shift from a reliance on external nonessential attributes to an orientation on essential ones. But in order to arrive at a recognition of objects it is necessary also to take into consideration the logical rule of associating an object with a concept. To discover this independently is not so simple and for that reason instead of orienting themselves on a system of necessary and sufficient attributes many students orient themselves only on individual isolated properties. The process through which that part of the orienting basis of action is identified in the case of actions concerned with the association of objects with concepts sometimes requires several years, but even then many students possess an incomplete orienting basis and the corresponding action of associating an object with a concept remains unreliable. In particular a study carried out by M. B. Volovich (18) produced the following findings. This related to 252 students drawn from the eighth and ninth grades of five Moscow schools whose general achievements were good or excellent, and who were taught by eight teachers. They were asked to carry out 10-12 assignments concerned with associating indicated objects with such concepts as "a bisectrix", "mutually perpendicular straight lines", "adjacent angles", "vertical angles". In one half of the assigned problems the objects were represented in drawings, while in the other half they were presented through verbal descriptions. In terms of content there were three types of problems: with incomplete definitions, sufficient definitions, and excessive definitions.

It was found that of 1,440 problems requiring that an object represented on a drawing be associated with one of the indicated concepts only 875 (less than 61 per cent) were solved correctly. Such a large ratio of errors in solving elementary problems is explained by the fact that students relied more on their visual perception than on instrument indicators. A specific feature of the problems was this: the figures were unfamiliar in appearance (for example, a right angle was located at the apex of a triangle and was also divided by rays into a number of other angles).

We thus see that even in upper grades students continue to be tied to drawings, and that by no means all students are able to generalize and abstract essential concept attributes.

The results were still worse in the case of problems with insufficient definitions. Only 35 out of 450 problems were solved correctly (less than 8 per cent). As we see the logical part of the orienting basis of action was not fully assimilated even by good and excellent upper-grade students.

Various errors, which have been interpreted as normal stages in the process of assimilating concepts, are thus in fact consequences of the unorganized assimilation of the actions underlying the concepts. This leads to the development of an inadequate orienting basis of these actions and to an insufficient level of generalization in assimilating its content. But as has been shown a specific characteristic of the development of man's cognitive activities lies in that each person does not discover logical rules of thinking anew and does not create systems of concepts, but assimilates them with the help of other persons as the experience of older generations. In the case that has been considered, on the other hand, students were not shown the operational aspect of the action of associating an object with a concept, and they were not given the system of guidelines required for its execution. This is why we believe that it is impossible to study the actual nature of the specifically human way of assimilating concepts (knowledge) in situations in which corresponding actions proceed in an unorganized manner. Instead a goal-oriented context for developing them is needed within which all the conditions required by the regulation of that process are met.

2. The Quality of Developed Actions and Knowledge in Experimental Studies

We usually evaluate the assimilation of actions and concepts in terms of the characteristics listed below.

The Rationality of the Students' Actions. Under rationality we have in mind the orientation of students on the complete system of essential attributes.

In order to establish the rationality of actions as a diagnostic means we employ three types of problems: a) problems in which a full list of conditions is presented, but the drawing does not correspond to these conditions; b) problems with inadequate conditions and without a drawing; c) problems with inadequate conditions and with a drawing that does not correspond to the specified conditions. (For example, it may be stated in the conditions that two equal angles are given possessing a common apex. It is asked whether they will be vertical. The corresponding drawing represents vertical angles. The correct answer is: "It is not known", since it is not indicated whether the sides of one angle formed straight lines with the sides of the other. This type of problem combines, as it were, the characteristics of the first two.)

It is desirable to initiate the verification of rationality by assigning problems of this type. If the student is able to solve them, this provides a sufficient indicator of the rationality of his actions. Indeed, such problems may be solved correctly only in the presence of an orientation on a generalized system of essential attributes and on the logical rule of identification. If students orient themselves on diagrams they will inevitably make an error. If they consider only individual essential attributes they will also make an error. Finally, the solution of these problems requires a knowledge of all conditions of all possible cases in solving problems on identification.

The use of problems in which verbal conditions and visual data are distinguished in order to test rationality is useful in a relatively large number of cases (biology, geography, physics, etc.), even though they may be limited by the specific features of the given area. Problems with insufficient conditions may be employed for diagnosing the rationality of assimilation of any concept.

The Presence of Conscious Awareness in Assimilation. In their work with concepts our students acted correctly and presented correct substantiation for their actions.

As has been noted under conventional forms of school instruction a high ratio of students beginning to study geometry are unable to substantiate their actions (174). This is also true of many students in the upper grades. When asked "Why?" they either do not answer at all or give incorrect grounds or finally refer to the diagram: "One can see that they are equal." Thus, in studies carried out by M. B. Volovich (18), good and excellent students from the eighth and ninth grades provided incorrect grounds for associating objects with the concepts "adjacent angles" and "vertical angles" in 558 cases out of 680 (81 per cent). In particular, 70 per cent of the students who correctly identified vertical angles and were asked: "Why do you think that they are vertical?", replied: "Because they are equal." At the same time students made use of all the attributes mentioned in the definition in performing the act of identification. Thus, while their practical operations are correct students are unable to prove this, and are not aware of the nature of their actions.

When assimilation is regulated both concepts and the actions on which they are based develop in a conscious manner from the very first.

The Confidence of Students in Their Knowledge and Actions. Our students displayed not only rationality and an awareness of the nature of their actions but also a great confidence in their actions. This expressed itself in a diversity of ways.

In one of our studies (164) in developing the concept of supplementary angles we made use of a definition that is usually found in geometry textbooks, namely, "two angles possessing a common vertex and a common side". In short, the necessary and sufficient attributes were: a) two angles, b) these angles have a common vertex, c) these angles have a common side. A sixth-grade student, N., stated that an angle and a part of that angle that was supplementary to one of its sides was such an angle. When we sought to object she replied that this matches the specified attributes. Since we saw that she was pointing to a clearly different type of angle we persisted in stating that she was wrong. In the course of verification experiments it became apparent that that student lacked completely an understanding of geometrical knowledge and that she was not certain of any of her answers. As soon as the teacher would question her findings she would immediately abandon them. This student was repeating a school year and consistently received a D in geometry. But now she was arguing with the teacher in seeking to prove that she was right. And indeed she was: for the definition that we have given her the angles that she had found were appropriate since they possessed all three indicated attributes. It is in this way that we discovered that textbooks provide an insufficient set of attributes which must be complemented by one more, namely one which excludes the presence of common points in these angles' internal regions. (Our students have helped us find the logical inconsistency of a number of definitions in geometry textbooks relating to vertical angles, adjacent angles and others.)

In a number of studies we deliberately created provocative situations and sought to force students to orient themselves on external nonessential attributes. Thus in the study carried out by E. I. Kochurova average students studying zoological concepts (fish, birds, mammals) were given images of animals belonging to a particular class and were asked to identify them. These images were selected in such a way that in terms of their external appearance the animals belonged to another class (dolphins, whales, bats). The teacher who, for example, would show an image of a whale would say: "Now this looks like a fish, does it not?" Usually the students answered approximately as follows: "It may well resemble it but now we will see just what it is." This was followed by an analysis of attributes on the basis of which the students then gave their answer: "This is a mammal, not a fish." The students were aware of the apparent noncorrespondence of the objects associated with a particular class. For example, having placed bamboo in the group of grasses they would say: "And yet one could easily think that they belonged to cords" (171).

Similar responses were found among children of preschool age. Thus Lopez (92) carried out a stage-by-stage development of the Vygotsky-Sakharov artificial concepts. Only three out of one hundred students made errors in the check test, in which essential attributes and associated attributes (colour, form) were distinguished. The students oriented themselves correctly on essential attributes and received new groups of figures that differed in their colour (form), while in the groups that were created after the learning process all figures were of the same colour (form). The teacher insisted that the figures were not placed correctly. "Is it permissible to place both blue and green figures in the 'bat' group? You know that we had only red objects in that group. Take these toys away, they were placed in the wrong playhouse." He was saying this persistently and even angrily.

It is well known that preschool-age children may be easily influenced and easily respond to the authority of adults. In that case, however, the children did not agree with the teacher, argued with him and sought to prove to him that he was mistaken: "So that can be blue. That too is 'bat' the others were a red 'bat' and that is a blue 'bat'." Some of the students became angry and were outraged at the teacher's behaviour: "But you yourself said that we should check the height and the base. This toy has both, as does a 'bat'." As a result, in spite of this provocative type of behaviour on the part of the teacher, only 5 per cent of the students agreed to abandon their correct initial solution. Seventeen per cent of the students vacillated. At first they insisted on the correctness of their solution, then abandoned it, but then eventually returned to their initial view. Seventy-eight per cent of the students were sure of themselves. They were ready to argue with the teacher and saw the teacher's annoyance at their behaviour but nevertheless would not agree to group figures simply according to colour or to form.

These data provide grounds for questioning the view that preschool children may easily be influenced because of their age. We believe that this characteristic exists whenever the child masters actions in an unorganized manner, as a result of which the actions often prove to be insufficiently rational, unconscious and unsuitable for independent applications, particularly in new situations. Conversely, in those cases in which actions appear as an object of special assimilation and where the course of their development is regulated, actions and knowledge are developed as rational, conscious and independently controllable. This causes the children to act confidently in ways that are appropriate to particular situations. Confident behaviour, of course, depends on a number of other factors as well, but the fully developed state of the actions underlying decisions concerning which doubts may arise is the principal factor.

The Absence of Ties to an Object's Sensory Characteristics. It is widely accepted in educational psychology and child psychology as well as in didactics that one of the characteristic features of a child's thinking concerns its orientation on visual elements as well as on practical and sensory elements. This was particularly evident in experiments on the assimilation of concepts. Any sensory attribute that may be common for a number of objects of the given class plays a greater role than do essential attributes specified in the definition (70; 125; 67).

N. A. Menchinskaya proposed the principle of changing nonessential properties, and above all of sensory properties, in order to oppose such influences and to facilitate the process of identifying essential attributes. Without denying a certain relevance of that principle under conditions of unorganized or poorly-regulated concept assimilation we wish to observe that at the level of theory this lends support to a sensory, mechanistic view of the process of concept assimilation which is thus perceived in terms of an analogy with producing a Galtonian photograph. The common attributes that are identified under such an approach with the essential ones operate repeatedly on man's mind, and each time this intensifies the reflection of what is common, while nonessential attributes tend to fade in the course of time and to be left out of the concept's content because each time they appear in a new specific form.

By directing attention to the subject's activity the approach that we are considering makes it possible to overcome mechanistic views of the process of concept assimilation. For it emphasizes that in fact the subject actively interacts with the world of objects and that his actions and activities operate as a mediating link between the external world and images that reflect that world.

If we turn to an analysis of the process of concept development under the usual approaches to instruction we will see that the attachment of students to sensory object properties results from a poor organization of their activities. We have already noted that definitions of concepts are usually introduced in a purely formal manner. It is presumably expected that students will then themselves decide how they will be employed in analyzing specific objects. But since the use of a definition in analyzing concrete objects presupposes an entire range of specialized knowledge and abilities (a knowledge of logical rules, a working knowledge of methods for identifying concept attributes within objects, etc.) most students are in fact unable to assume that task, and hence learn to differentiate objects by orienting themselves on superficial properties. They thus become dependent on external sensory attributes not as a result of their own thinking but because they do not possess anything more reliable. As soon as they are given means for orienting themselves on essential properties, which are often not very evident, they are able to rely on them and cease to be influenced by nonessential properties, even when the latter are vivid and constant.

This was already evident in our initial studies on the development of concepts. As has already been noted, in teaching geometry, we introduced problems in which the drawings did not correspond to stated conditions. Let us consider an example of the way in which the behaviour of students changes following a conscious assimilation of a mode of action.

In carrying out a diagnostic experiment a poor student, N., was given a problem in whose conditions all necessary and sufficient attributes of a bisectrix were specified. It was then asked whether the line specified in the problem's conditions would bisect an angle. An accompanying drawing was given, on which the straight line was represented in a position clearly different from that of a bisectrix.

At first the student stated that the straight line would be one that bisects the angle. "If we use a protractor . . . at first one should measure with a protractor." After measuring she found that the angles are not equal and refuses to declare that the line is a bisectrix. She then reads the problem specifications once more, which state that a straight line divides an angle into two equal parts, and says that the line divides only the angle DAC into equal parts.

TEACHER: Where, then, are the equal parts?

STUDENT: The side AB is equal to the side AD, while the side AC is not equal to the side AD so the straight line will not be the bisectrix.

As we see this student is unable to free herself from the difficulties produced by differences in the specified conditions and in the drawing. She readily abandons her answer and arbitrarily changes the attributes of the bisectrix.

In a teaching experiment after reading the same problem the student quickly begins to describe these conditions out loud.

TEACHER (*interrupts*): Have you solved the problem?

STUDENT: Yes, the drawing belongs to another problem: the specified conditions indicate that it is a bisectrix but that is not so on the drawing.

TEACHER: Why did you decide that it is a bisectrix?

The student correctly lists the attributes of the bisectrix, points to their presence in the problem conditions, and adds: "On the drawing the line has the following attribute in common with a bisectrix, namely, that a straight line leaves the vertex, but it does not divide the angle into two halves." She rapidly measures the angle with the protractor: "One is forty degrees and the other is ten degrees" (163; 164).

We see that the student clearly identified the necessary and sufficient attributes and made use of them correctly in a case in which the drawing did not correspond to the problem's conditions. Earlier this served as a source of confusion. This is especially interesting because N. had not worked on developing the concept of a "bisectrix". She assimilated the method of action in relation to attributes in the course of the working on such concepts as "straight lines" and "angles" and then transferred that method to the concept a "bisectrix".

Another example is equally suggestive. A fifth-grade student of average abilities, K., was deliberately given straight lines only in a horizontal position in developing the concept a "straight line". A preliminary interview indicated that the student considered only horizontal and vertical lines as straight lines and viewed sloped lines as slant lines: "This is not straight," she would say and we would deliberately not correct her. A horizontal line was also drawn on the card of attributes that she was given. The first six problems were accompanied by horizontal straight lines. The student tested them with the help of a tightly-drawn thread. The seventh problem related to a vertical line. In the eighth problem a sloped line was given. The student was asked to state what kind of line this was without reading the problem and without using the thread. She quickly and firmly replied that it was a straight line. When asked why she thought so she replied: "It will match a taut thread." Thus, it is only the thread that had become a reference standard for a straight line—a thread which had been given her and with which she worked.

Subsequently, she was given a cluster of straight lines. She answered confidently that they were all straight.

A similar development occurred in the case of other students as well: they shifted from drawings and sensory perceptions of properties to an analysis of verbally given data whose correspondence to a system of necessary and sufficient concept attributes determined their answer. It is characteristic that when we asked them to represent a particular geometric figure on the drawing they could represent it in different spatial positions and designate it by different letters. In other words, they did not display a type of standardized approach to representations that are so characteristic of teaching at school. This also indicates that these students were not tied to specific object characteristics identified through sensory perception.

Yet, it would be wrong to think that these students did not require any sensory data. As we observed the various groups of students we noted that some solved the assigned problems without sensory support altogether,[1] others relied on representations, still others sought to "represent" specified conditions in space, while still others asked permission to draw a sketch on paper (and then frequently represented figures that did not correspond to the indicated conditions in terms of their sensory properties). This last point indicated that for such students drawings served as a conventional carrier of essential attributes rather than as a part of problem specifications, and that they merely played an auxiliary role or perhaps merely the role of a specific instance (164).

The traditional view concerning the role of sensory properties in the thinking of children was conclusively disproved in the study of Lopez (92) mentioned earlier and which related to Cuban children between the age of six years and six years and nine months. As has already been noted each group of children had been given figures of only one colour or else one shape, but these attributes were, in fact, not essential to the development of corresponding concepts. The essential attributes were the area of the base and the height of the figures. These are more difficult to capture in sensory form and are not as easily seen as colours and shapes (studies on child psychology have long shown that colour and form are leading attributes among preschool children).

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[1] This does not mean, of course, that they did not require any materialization: we are referring to the solution of problems presented in check tests after the material stage of the action had been completed.

Yet, check tests have shown that 97 students out of 100 oriented themselves on the area of the base and on the height of figures. These attributes were in fact viewed as the leading ones, since in the process of concept development they were employed as the standard with the help of which each object was examined in establishing whether it belonged to the given class. Thus, in relation to preschool children as well it is possible to affirm the same point as in the case of children of average school age, namely, that when the colour and form of objects are perceived as leading object properties this is because they are not taught to rely on other properties and are not provided with means to identify them.

While form and colour are identified more readily than other properties this does not mean that children always view these properties as decisive. Thus, the experiments that have been described suggest that the role of sensory properties in the thinking of children have been overemphasized. Children become prisoners of concrete data only when they are not provided with modes of action that permit an orientation on other, more essential properties.

The State of Generalization of Concepts and Actions. We have studied the state of generalization of concepts and actions being developed in two ways. First, we have verified the ability of students to apply the concepts and actions that were developed in conditions that differed in some respects from those in which the concepts and actions had been taught. Second, we have studied the influence of the newly developed concepts on the subsequent process of development of new concepts, both from the same area of knowledge and from substantially different areas of knowledge. In other words, we examined the possibility of "transferring" concepts to new situations, which is, as we have already noted, an indicator of the state of generalization of the elements of cognitive activities that are being "transferred".

In the first case students were asked to identify objects of the same class but in different specific conditions. Sometimes we altered substantially some nonessential object attributes. For example, while the concept would be developed in the context of a particular spatial position of relevant objects check tests presented these objects from the given class in very different spatial positions (164; 165). Without changing the material, colour and form of objects in the process of teaching we gave check tests in which objects of the given class possessed another colour or another form, or else were made from another material (176; 92). Students who were taught with the help of our method were able to orient themselves correctly in new situations and the concepts that had been developed were applied successfully in identifying new objects related to those concepts.

In some of the studies the element of novelty in specified conditions was provided by presenting objects of the given class jointly with other objects; during the teaching process the objects belonging to a given concept were presented as independent objects, while in check tests they were elements of other objects. The figures to be identified were presented in two ways: a) with a clear specification of the attributes of the given concept (for example, it was stated in a problem that the angle of a parallelogram was divided by a ray passing through its vertex in a ratio of three to four. It was asked whether that ray would bisect the given angle. The students had not seen parallelograms before); b) with an implicit indication of attributes necessary and sufficient for associating an object with a specified class of objects. Unlike in earlier problems the conditions did not contain direct information concerning the object attributes, but these could be inferred indirectly. For example, conditions might specify adjacent angles and indicate that a bisectrix passes through each of them. It was asked whether these bisectrices would be perpendicular to each other. As we see, these conditions do not directly convey any data concerning any of the necessary and sufficient attributes for establishing the presence of perpendicularity. The first attribute (a straight line) is conveyed through the indication that bisectrices are drawn (a bisectrix is a ray). In order to establish the presence of the second attribute (they form a 90 degree angle) use must be made of a property of the bisectrix (it divides the angle in half), and of the property of adjacent angles (their sum is 180 degrees) and to apply approximately the following reasoning: "1) Each bisectrix divides the angle into two equal parts. Accordingly, each of the adjacent angles is divided into two equal angles. 2) The angle between the bisectrices is composed of halves of adjacent angles. This means that it is equal to the two remaining angles. 3) The adjacent angles taken together are equal to 180 degrees. Accordingly, the angle between the bisectrices will be one half of 180 degrees, i.e., 90 degrees."

Without pausing to consider an analysis of solutions of problems of the first type we shall merely note that they did not pose any difficulties.

The solution of problems of the second type calls for a special discussion. Two research studies were carried out in order to establish the specific features of the students' orientation in situations of this type, which are far more complex. They related to elementary geometric concepts (lines, angles, a bisectrix, adjacent angles, perpendicular lines, triangles).

In the first study, which we carried out jointly with K. A. Stepanova (174) the group was composed of thirteen fifth-grade students whose performance had been poor and who had never studied geometry. In instruction they were given only problems in which the necessary and sufficient attributes of the relevant concept were presented in an explicit and direct form. The search for attributes was thus made as easy as possible. The series of teaching experiments did not teach students to find attributes given in an implicit form; they merely assimilated the action of associating objects with a concept in terms of attributes presented in an explicit form.

Once the action of associating objects with a concept was developed each student was given check tests in applying corresponding concepts. These specified the necessary and sufficient attributes of the concepts being verified in an implicit form. The degree to which they were implicit and accordingly the degree of complexity of the problem varied. In some problems one attribute of the concept in question was given in an explicit form while another was implicit. In other problems all attributes were given implicitly. In some problems, moreover, the finding of required attributes called for the use of one familiar concept, while in other cases this was two. In two of the problems the attributes being sought were presented through unfamiliar concepts. The solution of all problems was limited to attributes that had been specified in definitions of the corresponding concepts. None of the problems required the use of theorems and logical inference. Usually the problems were given without a drawing (drawings were given only when the student experienced difficulties).

Altogether 164 problems were given to 13 students. In 163 cases the students identified the attributes that were hidden in the problem's conditions and provided the correct answers; in 150 cases, moreover, they provided a correct substantiation. Similar results were obtained in a second study that was carried out jointly with G. A. Butkin (170).

It is characteristic that even when encountering unfamiliar figures the students felt confident, immediately turned to the necessary and sufficient attributes of the concept in question and employed them as reference standards. They sought the attributes in the problem's conditions, and the absence of a drawing did not impede a correct solution. Upon meeting an unfamiliar concept in the problem's conditions they asked for explanation. After the teacher had provided a definition of a new concept they repeated its attributes (either out loud or to themselves) and compared them with those being sought. A large number of students expressed their reasoning out loud.

Those studies have thus shown that when students are taught to employ the necessary and sufficient attributes of concepts as an orienting basis of action in situations in which the object being defined may be directly compared with these attributes, they will subsequently employ them correctly in situations, that are more complex, in which a preliminary search is needed to establish the system of necessary and sufficient attributes.

The second approach to studying the state of generalization of the concepts being developed was concerned with studies of "transferability": the existence of a positive influence of assimilated actions and concepts on the development of new ones was established. We recorded instances of such transfers in the development of several closely related concepts. In a joint study with S. B. Mashkova (50) after developing the elementary geometric concepts "straight line" and "angle", we studied the specific characteristics that attached to the development of such concepts as "a bisectrix", "a perpendicular line", and "adjacent angles". It emerged that the assimilation of the specific part of these concepts proceeds approximately in the same way as in the case of the initial ones—there was no positive transfer; this means that the specific part of a developed action and concept is generalized only within the framework within which that concept was applied. As for the logical part of actions, its development in assimilating new concepts proceeded much more rapidly and more easily: it could be carried out immediately in external verbal form and even in a mental form. This indicates that as the initial concepts were developed students assimilated the logical part of actions in a generalized form that was also applicable to work with other contents.

Another study carried out jointly with E. I. Kochurova (171) established the existence of such "transfers" first with regard to concepts that are related to some extent but are more distant than in the case that has just been examined, and second in relation to concepts from an altogether different area.

These studies refer to a group of 16 fifth-grade students of average performance, who had not studied geometry in school. The teaching series of problems related to elementary geometric concepts: straight line, angle, bisectrix, supplementary angles, adjacent angles, and vertical angles. As in the other studies these concepts were developed through the action of associating objects with concepts.

Once the students had assimilated that action and concepts they were given a series of check tests, in which they were also asked to carry out the action of associating an object with a concept. The concepts, however, were not familiar ones. They were borrowed not from plane geometry but from stereometry, botany and zoology. The concepts borrowed from stereometry were a "prism" and a "truncated pyramid". Those borrowed from botany were "herbaceous plants" and "ligneous plants", while the concepts "fish", "birds" and "mammals" were borrowed from zoology.

It is important to note that the material was selected deliberately in such a way that one could not judge by appearances alone to which concept the given object belongs. Thus, in the case of some of the truncated pyramids the difference between the upper and lower planes was so negligible that they could easily be taken as prisms. In the botanical series the plants that were listed included papyrus and bamboo, which are tree-like in terms of their external appearance, even though they are in fact herbaceous plants. Conversely, ivies and dwarf trees resembled herbaceous plants in their appearance. Finally, the animals included dolphins and seals, which are mammals that may easily be mistaken for fish. Nor is it easy to recognize that a bat is a mammal since it is more like a bird in its external appearance. The variety of fish was especially great: it included flying fish, sea horses, and fish whose appearance was similar to snakes.

A relatively detailed description of each animal or plant was presented on the reverse side of each card carrying the corresponding drawing. The descriptions contained many nonessential attributes but always contained essential ones as well. The name of the class to which the animal or plant belonged was, of course, not indicated.

Twelve (75 per cent) of the sixteen students soon stated that in order to solve the problems it was necessary to know the relevant attributes and asked what they were. The teacher gave cards to everyone on which the attributes of the corresponding concepts were written and pointed to the texts containing descriptions of the plants, animals or figures being considered. Four students initially sought to identify the drawings by their external appearance. But after the teacher had asked whether it was possible to place the cards in some other way, they firmly answered that "they may be placed in terms of attributes". Let us consider a typical passage from the minutes of an experiment. A student, S., decided to divide animals into three groups by their external appearance.

TEACHER: In what other way is it possible to solve that problem?

STUDENT: It may be done by attributes but we do not know anything about animals and we do not have attributes.

TEACHER: And what if I should give you the attributes?

STUDENT: Then it would be possible.

After receiving the cards with attributes all students usually stated the same point as T.: "I thought about attributes right away but then I thought that I do not know the attributes for all these plants."

After receiving cards with attributes all students proceeded confidently: they read the descriptions, and sought in them the attributes that are necessary and sufficient to relate the object to the corresponding concept. At first they consulted their card and searched for one attribute after another, but after several problems they had memorized the attributes and did not consult their cards any longer. The students stated the attributes out loud and then sought them in the description. Towards the end of the experiment this was no longer necessary: they moved immediately to an analysis of the description and did this without voicing the attributes. But in those cases in which they encountered objects that did not match the concepts that were given they first made several attempts to carry out the action of association in mental form, and then occasionally shifted to an action in which they relied on the card on which the necessary and sufficient attributes of the corresponding concept were listed. In most cases this occurred in relation to objects that possessed some attributes matching the necessary and sufficient attributes of corresponding concepts (for example, in relation to a turtle, students discovered that it lays eggs, yet that attribute had been mentioned as one of the necessary attributes of birds).

Initially the analysis of the objects that had been given proceeded slowly and in extended form, but gradually it became more rapid, and eventually students started to provide the answers immediately after reading an object's description. It is characteristic that at no time did they yield to the temptation of relating an object to a particular class of objects on the basis of external appearance alone, without establishing the presence of the system of necessary and sufficient attributes of the corresponding concept. Even in those cases in which the teacher provoked them to follow an orientation on external attributes they proceeded correctly, applying the actions that had been assimilated in work with concepts from another area.

All students solved the check tests. It should be noted that they were given a classification problem, that is, a problem that is more difficult than the identification of individual objects in the process of learning.

This study has thus shown that the logical content of the action of associating an object with a concept may be developed in a generalized form already in work with the most elementary scientific concepts, and may subsequently be applied without further learning to any concepts possessing the same logical structure of attributes.

That conclusion was confirmed by experiments with preschool children. Kh. M. Teplenkaya (176) carried out a study involving 48 children between the ages of six and seven. It was concerned with the action of associating an object with a concept and use was made of the four artificial concepts of Vygotsky-Sakharov. All conditions required for a regulation of assimilation processes were met.

Following a verification of possibilities for applying the newly developed concepts in new conditions (through an introduction of new nonessential object properties) the students were given the same problem on the classification of animals by classes—mammals, fish, birds—as in the study of Kochurova. Since the children did not possess any biological knowledge and could not read, distinguishing attributes of each class were named to them as essential attributes (mammals feed their cubs with milk; fish breathe with gills; the bodies of birds are covered with feathers). Because the test was concerned with the transferability of a logical rather than a specific part of the concept the nature of the distinguishing characteristics did not play an essential role.

The children experienced difficulties because for the first time they found themselves in a situation in which judgement on the basis of a direct impression and judgement based on logical means contradicted each other. (In the teaching series of problems the perceptual image of the objects did not contradict their logical evaluation.) Nevertheless all children classified animals correctly. After they were given a problem they immediately turned to the teacher and asked: "And which attributes are important?" The teacher would name the essential attributes. Subsequently the children would take the card with a drawing of the animal and would ask the teacher whether the given animal had the attributes of a particular class.

It is characteristic that the order in which the children asked questions concerning individual attributes was not arbitrary. They always asked first whether the animal in question possessed the attributes of the particular class that was suggested by its external appearance. In the case of whales, for example, attributes relating to the class of fish were mentioned first ("How does it breathe?"). When it turned out that the animal did not possess the attribute of the corresponding class the children shifted to establishing the presence of attributes typical of other classes.

The conclusion that the animal belonged to a particular class was always reached on the basis of the attribute that was mentioned to them as essential ("important").

A transfer of the logical part of the action of associating an object with the concept thus did take place among preschool children. It is particularly interesting that it occurred under conditions in which conflicts arose between the child's "worldly" experience and the experience acquired in the course of learning. This confirms Vygotsky's view that the assimilation of scientific concepts produces a restructuring of "worldly" concepts and "elevates" them to a scientific level.[1]

In analyzing the structure of actions, the objective content of elements constituting that structure, and the nature of their relations, it is possible to indicate in advance the possible limits of generalization. Theoretical analyses and experimental data have shown that possibilities for transferring different structural elements constituting cognitive actions vary. Naturally, the specific part is much more limited in its transfer possibilities than is the logical part, which does not objectively depend on the specific content of concepts and actions. But actual possibilities for transferring, and accordingly the level of generalization of particular types of knowledge and actions are determined not only by their objective content but also by the quality of assimilation.

Our studies have identified a number of conditions that contribute to the transfer of assimilated actions.

If actions did not appear as objects of assimilation in the course of learning, developed in an unorganized manner, and are not consciously performed, then they may be applied effectively only in relation to the particular concepts on the basis of which they were developed and cannot be transferred to other concepts. This was established in studies carried out by E. I. Kochurova and Kh. M. Teplenkaya.

Unlike in the classical methodology of Vygotsky and Sakharov in which artificial concepts were developed under conditions in which the objects possessed two essential attributes (the area of the base and the height) and two nonessential attributes (form and colour) real scientific concepts were developed in the studies of Kochurova (77) in relation to objects possessing two or three essential attributes and three to five nonessential ones. Another difference concerned the fact that in that case each concept was developed separately, and the student was given only those figures that had served to develop the corresponding concept. They included both figures that related to the given concept and figures that were unrelated to it. The latter possessed either individual attributes of the concept that was being developed or else nonessential attributes that always accompanied essential properties of the particular figures in relation to which the given action and concept were developed.

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[1] This problem will be examined more closely in Paragraph 5.

Geometrical figures were presented in the form of either models or drawings. The attributes that were varied included the material, colour, size, spatial positions, proportions of elements, etc. Approximately 50 figures were shown to develop each concept. Students were drawn from the fifth grade. As in the experiments of Vygotsky and Sakharov students were first given a name and were asked to select all the figures to which that name applied. If they made an error they were given the name of a figure possessing another set of nonessential properties, etc., until each student was able to solve a problem correctly.

Eventually all students were able to solve the problems and to select correctly all figures relating to each of the three concepts that were named. The number of required trials varied from one to ten. Subsequently, each student was asked questions whose aim was to identify the attributes that had played an orienting role. An analysis of the answers has shown that the students were not consciously aware of the essential attributes and were not consciously aware of the fact that the figure could be related to the given concept only when all of them were present.

In a series of check tests one half of the students were asked to classify a number of animals into three groups: mammals, fish, and birds. Naturally, the students did not ask for any attributes from the teacher and oriented themselves on external appearances, on the basis of their own "worldly" experience. As a result, water mammals were described as fish and flying mammals as birds. Even in those cases in which students were given cards listing the attributes of particular classes this did not help much: "worldly" experience prevailed ("There are no fins so this is not a fish"). Answers were correct only in those cases in which essential attributes were combined with external properties that were familiar to the student in terms of his "worldly" experience. This confirms once again that it is not sufficient to merely specify a set of guidelines, and that an adequate action must be identified in relation to which they may serve as an orienting basis.

The experiment of Vygotsky and Sakharov relating to four artificial concepts were repeated by Teplenkaya (176). This related to developing four artificial concepts in a group of 11 children, whose age ranged from five and a half years to six and a half years. The findings coincided with those of Vygotsky.

Then the children were given the same problem of classifying animals as in the preceding study. Their actions were similar to those at the beginning of the teaching series, i.e., the problem was interpreted as being entirely new. While towards the end of the teaching series they had reached the level of pseudo-concepts and potential concepts, the check tests were carried out in terms of complexes of chains and associations.

They classified animals on the basis of their similarity to one of the apparent attributes of animals from a given class. In those cases in which the teacher named the distinctive attributes of each of the three classes of animals they were unable to make use of them. They would name some animal that was familiar to them from "worldly" experience and that possessed the given distinctive attribute ("I saw a dog and she was feeding her puppies with milk"), and then selected still other animals resembling the first in terms of altogether different attributes. Thus, the presentation of distinguishing attributes did not lead the children to understand the need to classify on the basis of a single and stable set of attributes.

In both teaching series the action of classification was thus assimilated by all students. But neither the content of that action nor the set of attributes in relation to which a classification was carried were consciously understood. As a result they were unable to make conscious use of the action that had been assimilated in order to classify new objects.

These studies have also shown that in order to achieve a generalization of actions that makes it possible to transfer them to new situations it is insufficient to merely organize material in the appropriate way: the students in this study were concerned with different types of objects of a given class during the learning process. Students were also given the basic types of logical situations bearing on identifying, were given variations of basic types of nonessential properties, and finally were given a system of sample objects from the given class. But all of this merely made it possible for them to differentiate objects at the visual level. It did not lead to a conscious awareness of their essential properties, which continued to be fused together with nonessential ones, and there was also no conscious awareness of the operations that were performed.

Our studies have also traced the dependence of generalizing activities on the type of the orienting basis of action that is employed.

In particular, in the study of Kochurova that was just considered it was found that the number of trials needed to select all objects relating to a particular concept depends on the level of generalization of the orienting basis that is given to the student. For example, in developing the concept of an angle, one half of the students were given an acute angle as their first sample and the other half was given a right angle. In the first case the number of trials was nine and in the second fourteen. Similarly, in developing the concept of supplementary angles the first group was given the general case of such angles, namely, the case of acute angles, and they required 11 trials. The second group was given a specific case, namely right supplementary angles, and required 18 trials.

In our joint studies with Yu. V. Yakovlev (175) comparisons were carried out to the effectiveness of teaching chess skills with the help of different types of orienting bases of action. One of the indicators of effectiveness was the range of situations in which the developed actions and knowledge could be transferred.

As in the other studies it was found that when an orienting basis of the second type was employed the corresponding "transfer" of knowledge and actions was limited. It occurred only in those cases in which a specific condition of a new problem was similar to conditions considered in the case of the teaching process. The dependence of transfers on the quantity of specific cases assimilated by the students was also studied. It was found that an increase in their number did not lead either to a greater level of generalization or to a conscious awareness of the particular conditions that underlie the solution of all these cases. The acquired actions were reasonable and conscious but were of a specific nature. Of course, as the number of specific skills increases, possibilities for transferring them also increase, since the assimilation of each new specific procedure represents an addition of a certain range of problems with conditions resembling those that were used in learning. But this does not produce any qualitative changes either in the abilities themselves nor with regard to their transfer boundaries.

These data confirm once more the incorrectness of the view that generalization is similar to a Galtonian photograph: an increase in the number of specific types of knowledge and actions does not lead to an "erasing" of some specific features by others and to the identification of what is general as a component that is intensified as each specific case is assimilated. As we have already noted the process of generalization is an active process that depends on the content of the orienting basis of the actions that are directed at the objects to be generalized. The nature of the orienting basis of action operates as a decisive condition determining the extent to which the knowledge and action being developed will be generalized. In order to develop generalized knowledge and actions it is necessary to include the essential attributes that underlie all specific phenomena into the orienting basis of action from the first. Each specific phenomenon will then be viewed from the first as a manifestation of what is general and essential, and will encourage the assimilation of the latter. This is precisely the manner in which we approached the development of the logical part of concepts, and succeeded in making it transferable to a large number of situations independently of the apparent similarity of the specific conditions of the problem.

Attaining a Specified Form of Action. In all cases in which the stage-by-stage development of actions was undertaken it was possible to carry them to the level of mental forms. Moreover, as has already been shown, actions in that form were transferred either fully or partly into situations that were substantially different and that called for a partial replacement of the orienting basis. In cases in which conditions were very complex the action fell back to genetically less developed phases—usually to the external verbal stage.

As has already been mentioned the attained form was identified by asking the students to carry out actions in corresponding forms.

The Stability of Newly Developed Actions. The tests that were employed to verify the stability of newly developed actions were not systematic: their stability was established only in some studies and with regard to some of the students. Nevertheless, whenever we verified the development of a concept and action after several months (from three to ten) we always found that the students displayed practically the same abilities as immediately following the learning process. Of course, no additional learning had taken place during the intervening time.

Thus in the study of M. B. Volovich (18), 94 per cent of the students who were given problems in identifying objects after a period of three months gave correct answers, and that number declined to only 93 per cent after ten months. With regard to problems concerned with establishing inferences from the fact that an object belonged to a given concept 95 per cent of the students gave correct answers after three months and 93 per cent after ten months. Approximately similar results were obtained with regard to other types of problems.

Similar results were obtained in other studies. It is important to note that the development of knowledge and actions not only made it possible for students to answer correctly, but led them to retain all the qualities mentioned above, such as rationality and a conscious awareness of their actions. For example, in one of our studies we gave students a problem five months after the concept a "perpendicular line" had been developed, in which it was asked how one would know where the lines on a drawing were perpendicular. Four perpendicular lines were represented on a drawing whose position was unusual, as well as one sloped line in a familiar position. The angle of the sloped line, moreover, was nearly a right angle. The students replied that one should measure the angles, and whenever the angle will be a right angle there will be a perpendicular line. When they were asked to estimate this visually they answered correctly. Thus, the students showed that, first, they knew the method for identifying objects, and second, that specific features in these objects do not prevent them from acting correctly.

While the testing of the stability of acquired knowledge calls for further studies the data that are already available make it possible to believe that the principles that were applied to the development of actions (and knowledge) resulted in much more stable assimilation of these actions and knowledge than in the case of traditional forms of teaching. This is explained by the fact that in usual school practice the assimilation of concepts occurs largely at the level of memory. The mental operations on which they are based are developed in a largely unorganized manner, and as a result not all students attain a capacity for conscious and autonomously controlled activity. In the case of our studies, on the other hand, these actions appear from the first as objects of special development and serve as means for assimilating concepts. The process of assimilating concepts is organized as a process of applying actions and a process of solving problems. The task of remembering is not presented to students as a distinct task.

The Reduction of Actions and Measures of the Extent to Which They Are Assimilated. Since the aspect of extensiveness cannot yet be clearly programmed and diagnosed we usually acquire only a general notion of that characteristic of actions by observing their execution. Indirectly it is possible to judge the extent to which an action is reduced on the basis of the increasing rate with which it is carried out. But that indicator also depends on its assimilation. Its reduction is a characteristic that is still insufficiently understood and for which there are no reliable diagnostic methods.

The findings that were described show that our approach provides for a development of cognitive actions (and through them of concepts) possessing not only a specified content but also a number of pre-specified characteristics. A concept emerges as an integrated image at the point "when the action on the basis of which it is formed having passed through a stage-by-stage elaboration becomes a generalized, reduced, automated, and subconscious mental process. A mental action in such a form is a *psychological mechanism of an abstract image*, a mechanism of its development and continued existence" (36, p. 465).

§ 5. The Ability of Various Age Groups to Assimilate Concepts

The studies of L. S. Vygotsky, Jean Piaget, and of many other psychologists have shown that pre-teen-age children are unable to undertake conceptual thinking—they merely employ various intellectual formations that functionally substitute for concepts.

Studies carried out by Soviet psychologists, and above all those that have been based on the theory of stage-by-stage development of mental actions of P. Ya. Galperin, have shown that children are able to assimilate abstract generalized knowledge already in the very first grades of primary school and in mass teaching conditions (D. B. Elkonin, V. V. Davydov, L. I. Aidarova, N. G. Salmina, V. P. Sokhina and others).

Studies of the process of concept formation among schoolchildren and the data suggesting that fundamentally new approaches to the formation of concepts may exist, have raised the question whether it is possible to develop concepts among preschool children. This was the objective of studies carried out jointly with Kh. M. Teplenkaya, G. P. Barayeva, and J. U. Lopez. Because the most comprehensive view of the formation of concepts under conditions of an unorganized assimilation of corresponding actions has been given by L. S. Vygotsky we have chosen to trace the process of assimilation under conditions of controlled teaching on the basis of the same material, namely, the four artificial concepts (bat, dek, rots, mup) so that the type of teaching would be the only new factor. The age of the children ranged from five to seven years.

In order to establish the level and course of the development of concepts in accordance with the methodology of L. S. Vygotsky and L. S. Sakharov among contemporary children we repeated in the studies of Kh. M. Teplenkaya L. S. Vygotsky's experiments with a group of 11 children whose age ranged from five and a half years to six and a half years. The findings matched fully those of Vygotsky (25). Children displayed only pre-conceptual forms of thinking. Nearly all forms of complex thinking were observed (the second phase of concept development according to Vygotsky): the associative form, the chain form, and the diffuse form, as well as pseudo-concepts. The phase of potential concepts (third phase) was also observed.

It was also established that the actual sequence of forms replacing each other in the course of concept development differed from the (logical) sequence described by Vygotsky.[1] The transitions that were observed were very complex and diverse. Eventually all children arrived at a correct solution of problems, but they never arrived at a solution through a conceptual identification of experimental figures. Essential attributes that they found in the process of practical action remained outside their conscious awareness and were not distinguished from other object properties. Their actual orientation related not only to those attributes that were identified as essential (the area of the base of the figures and their height) but often to colour and form as these related to the specific objects that were observed in experiments.

This confirmed once more that an unorganized practical adaptation to existing conditions through the method of "trial and error" that eventually leads to a correct outcome does not make it possible to become consciously aware of either the relevant conditions or the appropriate method of action. Vygotsky's and Sakharov's methodology yielded the same results for children in the 1960s as had been found earlier for children in the 1930s.

In teaching a second group of students (48 children ranging from six to seven years) all conditions required for regulation of the process of concept assimilation were present.

Without describing the methodology let us merely note that above all we did not require the children to identify distinctive attributes.[2] That had played a central role in Vygotsky's studies. Moreover, the attributes were not merely communicated to children but were included into the orienting basis of the action of associating an object with a concept that served as a means for developing these concepts. The fundamental difference between our methodology and that of Vygotsky concerned the fact that from the very first we identified not only attributes but also the method of acting in relation to them.

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[1] L. S. Vygotsky himself noted in his writings that the actual course of a process may not correspond to the logical course that he described.

[2] That methodology is described in an article by Kh. M. Teplenkaya (176).

Since we were studying processes of regulated concept formation we could not, of course, adopt the approach of Vygotsky and Sakharov. But we followed a course that was identified by Vygotsky's theoretical studies. We based ourselves on his proposition that any higher psychic function is at first an interpsychic collective and social activity and only later becomes an individual mental activity. We analyzed first the content of the action required for solving problems on identification. As has already been noted the basic operations constituting that action are the following: a) an identification of cognition attributes; b) establishing their presence (or absence) in each indicated object; c) a mental inference whether an object does or does not belong to a given class of objects in accordance with a logical rule of associating an object with a concept. An incorrect execution of any of these operations leads to an erroneous solution of the problem. Each of these operations, except for the first one, was then presented to the children in a material (or else materialized) form, and was assimilated by them under conditions of joint activities with adults. As it transformed itself from stage to stage the operation became an internal method of thinking.

The first operation, namely, the identification of the initial system of cognition attributes, may not be presented to children and elaborated by them in a goal-oriented manner in the same way as the other components that have been mentioned. The child finds an existing system of concepts in society. Each of them is a generalized abstract image of reality. But that image is one-sided and characterizes reality only from some particular point of view. Since reality possesses an infinite number of diverse aspects a very large set of different concepts may relate to a particular set of objects. In initiating the development of a particular concept we cannot indicate to the child a method that will make it possible for him to identify by himself the system of essential attributes that were included in that concept in the process of science's development. Such a method is hardly possible. The task of education as a specifically social process lies not in forcing children to discover anew a long-known system of attributes, but in employing it as a standard to "copy" a specific image from objects, and to see these objects precisely from the point of view that is consolidated within a given concept.

Accordingly, we did not require the children to identify the attributes that are hidden in each of the four experimental concepts, but communicated these attributes to them from the very first and taught them to search for them in real objects and to view these objects from the point of view of these attributes. As a result of a comprehensive elaboration of actions, of representing all their structural elements in a material (or else materialized) form, of implementing an operation-by-operation control over the execution of actions, and of implementing all other conditions providing for a regulation of the process of assimilation, all children oriented themselves on the particular system of attributes that was identified as essential (in the given case these were merely cognition attributes). The learning process required 11 to 16 sessions of 20-25 minutes each. Of 1,280 problems assigned to students in the process of learning, 1,253 (98 per cent) were solved correctly. As in the case of schoolchildren the errors were of an accidental nature, and were usually made at the external verbal and mental stages. All of them were corrected by the children themselves. We did not observe the stages of development of concepts indicated by Vygotsky.

In order to establish the quality of the actions and associated concepts that were developed check tests were given following the assimilation of the entire system of concepts. Their findings were described in Paragraph 4 of the present chapter in connection with the characterization of the element of generalization. As we have seen the children were successful in carrying out both the assignments that called for an application of the given concepts in new situations and assignments on the transfer of developed actions to new concepts. The experiments indicated that children are easily freed from an orientation on colour and form and can orient themselves on those attributes that are identified as essential without narrowing or widening the scope of the corresponding concepts.

In some of the check tests one of the essential attributes was deliberately omitted, and nonessential attributes (colour, form) were emphasized. When children would ask for a second attribute they were advised to dispense with it ("Perhaps you will be able to say whether this is a 'dek' without that attribute"). In these cases the children responded rationally, indicating correctly that they could not provide an answer ("If it is high it will be a 'dek' and if it is low it will be a 'bat'"). When the teacher gave a problem in which not a single essential attribute was specified children would state that it was not possible to solve that problem ("In such a case I cannot tell, it may be more than one").

Unlike in the case of students taught in accordance with the methodology of Vygotsky and Sakharov these students not only omitted the nonessential attributes from the concept's content but often did not even notice them. Following the development of each concept the teacher would ask such questions as: "How will you tell your parents at home which of these toys were 'bat' ('dek', etc.)?" In answering the children indicated only essential attributes. These questions were also asked as follows: "Can you say anything about this toy if you know that it is 'bat' ('dek', etc.)?" In such cases the children named only essential attributes and usually added that all other attributes may vary but one cannot say anything definite about them. These questions are also of interest because they require that the children carry out not merely actions of associating an object with a concept (moving from attributes to concepts) but the reverse action, namely, the action of inference (moving from the fact of the belongingness of an object to a given class to object attributes) which had not been developed. Nevertheless, in carrying out that action as well they relied only on the system of essential attributes. The fact that the children did not take nonessential attributes into account is indicated by the following: in repeating at the external verbal stage of action the conditions of the problem, they often named only essential attributes or else when they mentioned nonessential ones confused them with others. This indicates once more that only those aspects are reflected with which the subject interacts and which appear to him as the object of his own actions.

The process of concept development proceeded without difficulties. In developing the first concept the teacher's request that each operation be carried out in a particular sequence sometimes caused resistance. Gradually this became a customary mode of action that they employed easily and with pleasure. From an external "imposed" method, the action of associating an object with a concept was transformed into an internal mental procedure.

Since the logical part of that action was assimilated in a generalized form from the very first and remained the same in work with all concepts, the process of assimilation became more rapid as children moved from one concept to another. Transfers from one concept to another also took place in relation to the specific component of actions since for all four concepts the cognition attributes were associated with the area of the base and the height. Differences in attributes related only to their quantitative characteristics (greater than, equal to, or less than the reference standard). In developing the last concept the children themselves pointed to its set of attributes.

One could also observe a reduction of actions which is usual in such cases. At the external verbal stage this was expressed in the fact that the children omitted one of the postulates in carrying out a logical inference in associating an object with a particular class: they merely kept it in mind without naming it.

As the children moved from one concept to another they became increasingly self-confident in their reasoning. This was particularly evident in situations in which they were provoked to argue with their teacher and defended the correctness of their own position with conviction. This also confirms the element of conscious awareness in their assimilation of desired concepts and actions. The stability of newly formed concepts was established through check tests on the classification of animals. It has already been mentioned that unlike the children from the first group, these children relied on the logical procedure that they had assimilated rather than on their "worldly" experience. In such a context their "worldly" conceptions of fish and birds could be seen to undergo transformation, and with the help of that procedure were raised to a new level. The children did not express any doubt on findings obtained with the help of assimilated means in cases in which the latter contradicted their initial conceptions. On the contrary, they understood the erroneousness of their earlier conceptions ("It turns out that a whale is not a fish and I had thought that it was." If the teacher then said: "But it lives in the sea like a fish", this did not confuse the child: "It does not matter that it lives in the sea. It feeds its cubs with milk and that means that it is a mammal.") Having experienced such a transformation a "worldly" concept began to subsequently function in such a new meaning.

Thus, this study demonstrated that six- and seven-year-old children assimilate effectively the logical procedure of identifying objects, and on that basis the concepts corresponding to these objects as well. This study also established that the logical procedure employed in analyzing objects is developed more easily in conditions that exclude the possibility of identifying objects through a reliance on sensory images. It was reaffirmed by a comparison of the course and outcome of learning activities of the two sub-groups into which the students of the group were divided at the stage of material action. In the first sub-group (A) the figures that were identified were not removed but were grouped in terms of concepts and could always be seen by the students. Having been given a new figure a child could identify it not only by carrying out the indicated operations but also through a visual comparison with the figures of the corresponding class. In a second sub-group (B) visual comparisons were excluded: each identified figure was removed and students would always see only the particular figure that they were asked to identify. The experiments have shown that the process of development of actions and concepts in sub-group (B) occurred more slowly than in sub-group (A) but on the other hand the logical procedure for classifying objects was assimilated more clearly and more consciously in sub-group (B). This led to fewer errors and made solutions of problems in the check tests more rapid and more confident. Accordingly, the visual image that developed in parallel with the concept and which corresponded to the same content facilitated an orientation on objects in the course of learning. In new conditions, however, in which orientation on a visual image deviated with an orientation on concepts, this served as a perturbance that partly inhibited a transfer of the logical procedure of action to new conditions.

The ability of children aged six-seven years to develop concepts was again confirmed by J. Lopez (92) who employed the same methodology as Teplenkaya and applied it to 100 children in Cuba. The methodology differed only in that in the teaching series of experiments the nonessential object attributes (colour, form) were constant.

The experiments carried out by Teplenkaya were also repeated in every respect with regard to a group of 20 children, whose age ranged from four years eight months to five years three months. This was carried out by G. P. Barayeva (6). The objective was to explore the possibility that conceptual methods of action could develop among even younger children.

No substantial differences emerged in the course of teaching these children and children aged six or seven years. At the same time a number of specific features were observed in the case of the five-year-old children: their learning process required somewhat more time and the reduction in the action of associating an object with a concept proceeded more slowly; in addition, they made errors more frequently. In developing the first concept the five-year-old children did not accept immediately the dimensions of the figures as the only important attributes. At first they attached importance to the shape and especially to the colour of the figures. They named these attributes together with the essential ones. But already after four-five assignments they named only essential attributes. Finally, their wish to play with these figures was more pronounced.

Altogether the children in that group carried out 1,708 problems and gave 1,634 correct solutions (96 per cent). In carrying out the check tests on the classification of animals 80 per cent of the children immediately asked that the relevant attributes be indicated and on that basis classified the animals correctly. Twenty per cent of them did not ask for a specification of the attributes. Naturally, in seeking to classify animals visually they made errors. With the teacher's help these children became aware of the need to know the attributes of animals, and these were given to them. Subsequently, they carried out their classification correctly.

It is important to note that while in the initial stages of the learning process the perceptual image of objects interfered with the children's attempts to rely on logical means of object classification and led them to seek to orient themselves on the basis of external impressions. In the check tests this was no longer true: the logical procedure of associating an object with a concept was assimilated by the children and the vivid external appearance of objects no longer interfered with their activities, which led them to correct answers.

Subsequently, N. V. Yelfimova carried out experiments among six-year-old mentally-retarded children. Concepts were developed not one after another but as a system, that is, all four concepts were introduced simultaneously, and the methodology employed by Lopez was employed. These experiments demonstrated that these children, too, could develop a comprehensive generalization and carry the action of identification to the mental form. The course that had to be followed however was substantially different: it required more time and the creation of special conditions for sustaining the motivation that induced children to carry out the required action, as well as prolonged periods for carrying out individual components of the action involving both the child and the teacher.

The analysis of the process through which logical actions and concepts develop and the identification of its specific features require further studies with children of that age. Nevertheless, existing findings provide grounds for stating that the assimilation of logical methods of thinking is accessible to preschool children. This is also confirmed by the experiments of L. F. Obukhova (111; 113).

A comparison of the findings produced by our own methodology with that produced by the methodology of Vygotsky and Sakharov shows that the decisive factor determining the very great differences in outcomes is neither the children's age nor the nature of the concepts being formed (natural or artificial), but rather the manner in which they were formed.

* * *

The experimental data that we have presented show that we are indeed considering a fundamentally new approach both to the development and to the study of concepts.

The organization of conditions needed to regulate the process of assimilation made it possible for that process to proceed without substantial deviations and to produce mental actions that were rational, conscious, generalized, executed with confidence, and stable. This is true, moreover, not only of school-age children but of preschool children as well. These qualities make it possible to apply the actions that were assimilated not only in the situations within which they were developed but in new situations as well, that may be significantly more complex. The actions appeared to be transferable to a wide range of other concepts. This facilitates substantially the development of later concepts, both in the given area and in other areas, which in principle may be far removed in terms of their content.

This is precisely the type of process of assimilation that should be typical in the development of scientific concepts. Unlike in the assimilation of "worldly" concepts it may be regulated and is scientifically organized. The principles governing that process and the features characterizing it are those of the specifically social human procedure for assimilating experience. The process of assimilation appears as an ongoing transformation of actions while concepts appear as outcomes of that process that are intimately associated with the actions that serve to develop them.

The main feature of such an approach lies in that the teacher is able to follow the cognitive activity of students that leads to the development of concepts: the study of the specific features of that activity constitutes the psychological aspect of studies of the process of concept development, while a goal-oriented conscious utilization of these principles serves as an effective means of regulation of the process of knowledge assimilation.

In concluding the analysis of the studies that we have carried out the following should be noted.

In the studies that were considered the process of assimilation was traced only with regard to the properties noted in the definitions (descriptions). This refers to the beginning of the development of scientific concepts which become full-bodied only after they acquire a number of other object characteristics and after they find their position within the hierarchical system of concepts corresponding to the given science.

The further development of concepts requires that new actions be introduced, both logical and specific, in particular such actions as the inference from the fact of an object belonging to a particular class and comparisons of concepts. Studies have shown that the development of these actions generally proceeds in the same way (18; 17). The assimilation by students of new cognitive actions associated with objects of the given class implies a simultaneous further development of concepts relating to these objects that they have already assimilated. In particular, the development of actions identifying relations among individual concepts are especially important (joint subordination, genetic and species relations, etc.), which lend a systemic nature to the process of concept assimilation.

In order that from the very first concepts be developed not as an isolated instance of knowledge but as a structural element of a science it is very important to introduce concepts not one after another but in the context of a system. Studies carried out by L. A. Semenyuk (156), N. N. Nechayev (108) and L. F. Yermakova (60) have shown that in such cases it is desirable to rely on actions of identification and of classification.

Naturally, it is important to consider how widely the procedure for developing concepts that has been described may be applied. It may be applied in all those cases in which concept attributes are clearly identified and by their content are easily accessible to the student as an orienting basis for corresponding actions. In cases in which even one of these conditions cannot be met concepts cannot be developed with the help of this method. In cases in which scientific concepts are still not sufficiently clarified it is difficult to obtain the generally conceptual level of assimilation. In such cases assimilation will apparently remain at the level of a general representation. But in such cases as well assimilation can proceed only through a system of actions directed at the phenomena (objects) to be assimilated. But the orienting basis for these actions will be incomplete and not generalized and the development of the corresponding knowledge will largely proceed through a search for an orientation of a correct outcome from corresponding actions.

In those cases in which a scientific concept possesses a clear system of attributes but they are not accessible to students it is also impossible to rely on the actions of associating an object with a concept. In such cases, however, other systems of actions may be found that are adequate to the nature of that concept. Thus in the studies carried out under the guidance of Galperin (55; 43; 44; 149; 161), in developing the concept of numbers a measuring action was employed that led children to a correct understanding of numbers as a relation between the magnitude being measured to a unit of measurement. In such cases, however, the content of such concepts remains inaccessible to conscious awareness, and while the child acts rationally and orients himself correctly with regard to the counting system with the help of the concept he assimilated, he is not consciously aware of that concept's attributes and is unable to employ them with confidence in his own activities.

Since in the overwhelming majority of scientific concepts to be assimilated attributes are identified it is our view that the method of controlling the process of concept development that we have examined may be employed relatively widely.

Since the process of teaching is associated not only with the development of individual actions and concepts associated with them but also with the development of complex types of cognitive activities let us examine some problems relating to the programming of thinking procedures and to the control of their assimilation with the help of the theory that has been presented.

Chapter Four

PROCEDURES OF COGNITIVE ACTIVITY DEVELOPMENT

Usually in the process of solving problems individuals make use not of individual actions but systems of actions. Such a set of actions leading to the solution of problems of a particular class is usually called procedures or methods of solution. Since we are interested in the solution of problems from the point of view of the cognitive activities carried out by individuals we will call such a set of actions a procedure (or method) of cognitive activity.

The problem of thinking procedures and of methods for solving problems has long attracted the attention of psychologists and specialists in methodology. In particular, a large number of studies in that area have been carried out in relation to acquiring knowledge in mathematics. Such studies are concerned with the role of knowledge and of certain other factors contributing to the development of thinking procedures. They also identify individual characteristics of procedures, and elaborate rules and instructions that are intended to help students to "activate" the appropriate procedure.

One group of researchers takes the view that if students do not possess the required methods of thinking this is due to a poor assimilation of knowledge (see, for example, studies by Zykova [66]).

Other studies are concerned with identifying the conditions whose presence in the learning process contributes to the development among students of corresponding procedures. Examples are provided by the studies of E. N. Kabanova-Meller (71; 72) in which these conditions have been analyzed comprehensively. Without denying the significance of such studies it is important to note that the corresponding procedures and their structure and content remain poorly understood, and that the process on which their development is based remains hidden.

A number of studies have identified individual characteristics of the corresponding procedures and have shown the need for following the logic of their development. Thus in the study of F. N. Gonobolin (54), based on data concerning geometric forms of proofs, it was shown that at first the process of reasoning among students must be carried out in an extensive form and should be reduced only gradually. A large number of studies are concerned with the formulation of rules and instructions that are intended to direct students to the corresponding procedures and to guide their thinking in the required direction. A characteristic feature of these studies is that they do not analyze the procedure itself as an activity, and the problem of developing it as an activity possessing a certain content and certain qualities is not formulated. It is implicitly assumed in these studies that the students are able to carry out the required activities. It is assumed that thinking as a certain abstract function already exists and that the problem is merely to cause it to operate in a specified direction. Among these studies the works of G. Polya (280) are most widely known.

A fundamentally different and still not very numerous group of scholars recognize not only the need for developing generalized procedures of intellectual activity but also address themselves to the problem of identifying relevant components of that activity. This refers above all to studies carried out by the school of P. Ya. Galperin. They are concerned with the design of constructive models of the corresponding activities.

While the importance of modelling the activities to be programmed should be emphasized, it is also important to note that the effectiveness of a model will depend on the comprehensiveness of the structural and functional elements that it contains, and above all of the orienting basis of action.

Usually specific procedures for solving problems are modelled in the literature on methodology. It is also important to recognize that in these procedures only the executive parts of actions are noted, and as a result students frequently do not know why they should act in a particular way rather than in another. In teaching chess, for example, recommended procedures indicate which move should be selected in response to a particular move by the opponent, but neither the meaning of that move is explained, nor are the general principles that should guide the player in selecting a particular move. In such a situation the student can merely memorize mechanically the sequence of moves that bring him to his objective in accordance with a logic that remains hidden to him.

Identical activity procedures are frequent in mathematics as well. They are used especially widely in relation to geometric transformations and the solution of problems on the construction of figures. For example, a student is given a specific procedure for dividing a segment into two equal halves. The following operations are indicated: a) open the compasses to a radius larger than one half of the segment; b) place the leg of the compasses at the initial point of the segment; c) draw a mark above and below the segment (or else draw an arc); d) place the leg of the compasses at the terminal point of the segment and draw similar marks; e) connect the points of intersections of the marks with a straight line; the intersection of that straight line with the segment will be the mid point of the latter. Subsequently it is proved that the segments are indeed equal. Yet the entire process of dividing the segment into two parts is a purely mechanical procedure. The student does not understand why he should proceed precisely that way rather than another. Naturally such a procedure does not teach him to think and it may only be memorized. In fact the authors of such texts usually themselves recommend that the corresponding procedures be memorized (in order that they be "known").

Studies carried out on the basis of the theory of the stage-by-stage development of mental actions have shown convincingly that efforts should be directed at the modelling of general procedures of cognitive activities developed with the help of the orienting basis of the third (systems-oriented) type, or else of the fourth type.

Three fundamentally different approaches may be distinguished in the organization of the process of development of procedures of cognitive activity.

Under the first, which is used most widely, thinking procedures do not appear as special objects of assimilation, and their development takes place only in the course of solving problems in relation to which they appear as means and do not become objects of conscious awareness. As a result, the process of development of procedures of cognitive activities is prolonged and does not always lead to the desired results. In those cases, however, in which the required procedures are developed, the extent to which they are consciously recognized is as a rule insufficient, and they remain insufficiently generalized. As a result, their application is limited to the specific conditions under which they were assimilated.

Under a second approach procedures of cognitive activities are viewed as objects of special assimilation and as objects of regulation by the teacher. Persons who support such an approach, including ourselves, base themselves on their view that thinking is an activity encompassing different types of thinking that develop in the course of solving corresponding problems and that become mental as a result of passing through a number of stages that progressively replace each other. Thinking is thus not viewed as some already existing form of function that is applied, for example, to the solving of arithmetic problems, in carrying out geometric proofs.

We also share the view that in the process of teaching these procedures must first appear as objects of special assimilation in order that later they may be suitable for conscious and autonomous applications under new conditions. Finally, whenever this is possible general procedures of cognitive activities should be developed.

§ 1. Methods Employed in Modelling Cognitive Activity Procedures

In applying such an approach to the development of cognitive activity procedures the first problem concerns the modelling of programmed procedures: the identification of component actions and relations among them and the construction on that basis of a general set of instructions providing for the application of a given procedure to the solution of problems of the corresponding class. This objective may be attained in several different ways.

1. The Theoretical-Experimental Method

In the case of a theoretical-experimental method the modelling of the required cognitive activities procedure begins with the design of a preliminary model based on a theoretical analysis of the solutions of all problems of a given class and on an analysis of the difficulties that were experienced by students in practice.

Thus, in a joint study with G. A. Butkin (17) of the development of the general procedure of presenting proofs, the first component of that procedure, namely, the action of associating an object with a concept, was identified in a theoretical manner.[1] In analyzing geometrical theories and problems on proofs it may easily be seen that in geometry a large part of the theorems (problems) are concerned with demonstrating the presence or absence in the theorem (problem) conditions of a geometric figure belonging to the concept to which the conclusion refers. To prove means to establish whether the object given in the conditions of the theorem (problem) possesses the necessary and sufficient attributes of the concept specified in the conclusion. For example, to show that segments are equal means to associate with the concept "equal segments"; and to show that straight lines are parallel means to associate with the concept "parallel straight lines". It was therefore necessary to model that action. It shows the final objective (to associate with a concept) and the means for achieving it (to establish the presence among the given objects of one of the systems of necessary and sufficient attributes of that concept).

The need for a second action, namely, the selection of one of the equivalent systems of attributes sufficient for associating the object specified in conditions with the concept specified in the theorem's conclusion, was also identified theoretically. For example, in order to relate angles to the class of equal angles it is possible to achieve this by establishing the equality of each of them to a third angle; but this may also be achieved by showing that each of them is composed of equal parts, etc.

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[1] A number of actions relating to that procedure were identified in a general form by L. N. Landa (80). This work was continued in our own study which was concerned with a) modelling actions identified by Landa in a general form; b) identifying those actions that were not yet identified in that procedure; c) combining of actions into a general procedure as a form of activity; and d) developing a methodology of stage-by-stage formation of the general proof procedure. This last problem was the principal one.

The importance of that factor was shown by Landa (80). Our own problem was to establish how students may be taught to select one of the systems of attributes correctly.

The second stage refers to an experimental verification of the resulting model. The students who are selected for that purpose are either not familiar with the class of problems that will be solved with the help of the procedure to be studied, or else are familiar with the problems but do not know how to solve them. In the presence of all required regulation conditions these students develop the type of abilities that are identified in a preliminary analysis.

Observations of the way in which problems are solved in the course of instruction, and an analysis of the errors that were made as well as the results of check tests directed at verifying a diversity of qualities of the procedure that was developed make it possible to establish whether all components of the corresponding ability are identified and whether the sequence in which they were studied is correct. If it emerges that the preliminary model was incomplete (or incorrect) then a further development of that model occurs on the basis of an analysis of the results obtained. Thus, in the case of modelling the general procedure for proofs it became evident after the development of the action of associating an object with the concept that theorems and problems on proofs in which the identification of desired attributes required more than two logical inferences produced difficulties among students. This indicated that the action concerned with the identification of implicitly specified attributes should be subjected to special development. We call that action the elaboration of conditions in extensive form.

The third stage in working with the model thus refers to its further development on the basis of experimental findings.

A fourth stage concerns an experimental verification of the newly elaborated model. If it is found that activities that are developed in accordance with the model meet the specifications of the given class of problems it is then employed within the teaching programme. If, on the other hand, after an initial adjustment, the model is found to be inadequate, then it is developed still further on the basis of experimental data. In the case of modelling the general procedure for presenting proofs such a situation did arise: it was found that it is not sufficient to develop activities that included only the following three components: a) the action of associating an object with a concept; b) the action of selecting one of several equivalent systems of properties sufficient for identification (in that particular experiment this was achieved through an examination of all possible systems of attributes); c) the action of inference. These components did not lead to a process for producing proofs that was economical, nor did they provide for a sufficient selectivity and goal-orientation. The inference from conditions based solely on the action of extensive elaboration led to a situation in which students identified many unnecessary consequences that were not needed for the given proof.

In order to make the process more selective and economical it was necessary to make a process of inference of consequences more goal-oriented, and to teach students to first identify those conditions from which it is possible to arrive at relevant inferences for the given conditions. (For example, it makes sense to seek perpendiculars where there may be straight lines and where they may intersect at a right angle: equal adjacent angles, rectangles, bisectrices of adjacent angles, etc.) That additional component was identified after an analysis of the findings of an experiment and was called by Butkin an action in defining the areas of search. This action precedes the action of selection and provides a basis for it. It is also an action that is inverse in relation to the inference of consequences: one moves not from foundations to consequences but from consequences to foundations; in the given case the consequence is known (it is a system of necessary and sufficient properties for the given concept) and the problem is to establish a possible system of foundations.

In those cases in which there are several equivalent systems of properties sufficient for identifying the given object (several systems of consequences) it must be established for which of them causes do exist (areas of search). Once this is established a corresponding system of properties is selected.

Thus, an ability to carry out proofs emerged as a system consisting of four actions, each of which possesses its own function and is also related to other components in specific ways.

The action of associating an object with a concept plays a leading role within that system. The remaining three actions appear as necessary for carrying out that particular action. Indeed, the action of selection is needed in order to identify the particular system of attributes that will be sought in objects. The action of determining search areas makes it possible to identify that part of the conditions within which it is appropriate to seek for required attributes. The action of inferring consequences leads to an identification of attributes whose evaluation with the help of the action of associating an object with a concept leads to a conclusion concerning whether the specified object does belong to the concept appearing in the conclusion.

An analysis of the relations existing between these actions has made it possible to formulate a set of instructions relating to their execution, i.e., to model the procedure of the overall activity.

This set of instructions appears approximately as follows: 1) indicate what it is that has to be proved; 2) name the attributes with the help of which this may be done; 3) take the first system of attributes; 4) indicate the "area of search" for the first of these; 5) verify whether the corresponding figures are present in the statement of the problem's conditions, etc.

A specific feature of this method for modelling activity procedures is that it begins with an analysis of specifications that are objectively assigned to the human activity in the problem, for the sake of which that activity is developed. But it is also possible to proceed in a different manner.

2. Analysis of Mastered Types of Activity

That method for identifying components of the activity procedure that is of interest is more widely used in psychological and pedagogical sciences than is the first one. It consists of the selection of a group of persons who are successful in solving problems of a particular class. The fact that they are solving them successfully is viewed as evidence that the cognitive activities procedures applied by them are appropriate in relation to the specifications of the given class of problems.

At first it may seem that this method is simpler and more reliable. But in fact this is not the case. This is because already developed cognitive activities exist in the form of mental, generalized, reduced, and automated activities. In such a form it is quite difficult to arrive at their true contents. As an example, let us consider the action of defining an area of search. At first when that action is only being developed the student associates very slowly the system of attributes that makes it possible to establish the association of an object with a given concept with the particular problem conditions from which these attributes may be inferred. Initially they are taught to create areas of search on their own by assigning problems relating to the use of intermediate concepts. For example, it is asked that an angle be specified but in such a way that the word "angle" not be mentioned. In solving problems of that type students actually create areas of search for the corresponding concept. But after passing such an extensive form of the corresponding path in both directions students eventually instantaneously actualize that system of properties that may be employed in given conditions, i.e., the particular system of properties for which there is an area of search. In this way only the extreme links of an action relating to the determination of areas of search remain in the consciousness of the students, namely, the perception of the situation and the recreation of a corresponding system of properties that appear to be directly linked. Accordingly, in our early studies (162) we interpreted such a selectivity in thinking as an actualization of linkages (associations) between specific features of problem conditions (the type of situations that were specified) and the system of properties that is employed to identify it. In that same study we found that students who did not possess a selective thinking and relied on what they could see in problem conditions seldom arrived at a solution, and when they did it was always accidental: in examining all possible types of consequences they sometimes found those that were required. Those students, on the other hand, who carried out the required proofs quickly and correctly always began by defining the course that they would follow. For example, when it was necessary to prove that two segments were equal they would say: "In order to prove that two segments are equal it is necessary to consider whether it is possible to prove the equality of the triangles within which these segments enter as corresponding sides", i.e., the students immediately defined an area of search for the corresponding property. In some cases they were able to explain why they operated in this way while in others they could not, but in both cases their reliance on such a course usually led to a solution. Like a number of other authors we called this special knowledge which makes it possible to determine areas of search for solutions "operational propositions". But in recommending that students be equipped to use them we did not indicate how this should be done, i.e., we did not identify the actions that relate to the determination of the search area in their extensive form.

The role of operational propositions in geometric proofs has long been noted, but all attempts to introduce them into practice have failed. This is explained precisely because they were viewed as forms of knowledge, and an inability to see underlying actions led to recommendations to present these propositions in an already formulated form and to assimilate them through memorization (197; 11). These suggestions produced justified objections among a number of specialists in methodology who were opposed to a replacement of thinking by mechanical memorization procedures (e.g., 107; 53).

As a result the problem of developing so-called operational propositions remained unsolved. Our studies with Butkin have shown that operational propositions are reduced and generalized actions relating to the identification of areas of search in which only two links have remained consciously perceived: the initial link and the terminal one. It is natural that attempts to develop that action directly in a reduced form were unsuccessful.

This does not imply that the approach calling for an analysis of mastered activities must be fully abandoned. A knowledge of the principles governing the development of cognitive activities sometimes makes it possible to carry out an action "in accordance with a formula", to make it extensive and to identify its true contents. In such cases one may employ as an additional means an analysis of typical difficulties experienced by persons who are not effective in the given activity. An example is provided by the comparison of the process of proof that has just been mentioned for two categories of students.

§ 2. Types of Cognitive Activity Procedures and Their Development

In terms of their function it is possible to distinguish at least two types of general cognitive activity procedures: a) procedures that make it possible to carry out an independent analysis of all specific phenomena in a given area; b) procedures that make it possible to recreate a set of specific phenomena within a given area. The selection of a procedure follows from the objectives of instruction. In terms of their contents cognitive activity procedures may be divided into logical and specific ones.

In principle, the development of cognitive activities procedure may follow two courses: a) initially, individual actions are developed that constitute that procedure, and then they are combined into an integrated activity within which the sequence of implementation is specified by corresponding instructions; b) from the first the procedure is developed as an integrated whole.

The first course is selected in those cases in which the procedure is complex and component actions are new. The second course is usually employed in cases in which actions entering into the procedure are relatively simple or when most of them are not new.

As an example of a cognitive activities procedure of the first type leading to an independent analysis and to a transformation of specific phenomena resulting from a development of the first type (that is in terms of components) we may consider the procedure for arriving at proofs that we have examined earlier. That procedure has made it possible for students to prove a large class of theorems independently, but it did not permit them to formulate new theorems. In teaching that procedure individual components were first considered. Each of the actions was first developed individually with the help of specifications that provided for a regulation of the assimilation of process. Since these actions themselves consist of an entire system of operations, the operation-by-operation structure of each action was first identified, and a sequence was established for carrying out operations. In addition, instructions were given envisaging an implementation of all types of operations, namely, orienting operations, executive operations, and control operations.[1] Naturally, the actions were developed through their application to the solution of corresponding problems. Thus, in developing the action of inferring consequences problems of the following type were assigned: "Given a triangle, what else is thereby given?" Following the development of all indicated actions a general instruction was given for applying them to proving theorems and problems.

The overall procedure is programmed with the same qualities as the component actions. Nevertheless, another case is possible, in which the component actions, when developed in isolation from each other, are carried to the level of external verbal forms, while subsequent transformations occur in accordance with a procedure that is then programmed in terms of more exacting indicators.

It emerged that there was no fundamental difference in regulating the development of activity procedures by comparison with regulating that of actions. Initially the procedure is applied in a materialized (or else external verbal) form, and it is then gradually fully translated to the mental level. Corresponding problems are then naturally related to an application of the overall procedure rather than of individual actions. Thus, in developing the procedure for proofs elementary theorems are introduced as well as problems on proofs. Learning begins with the first stage, whose objective is the same as in the development of individual actions but applied to the overall procedure. In particular, students are shown how the given procedure should be carried out and are provided by the required explanations.

In illustrating procedures of the second type which make it possible to recreate specific phenomena from a given area, let us consider the general procedure for carrying out elementary geometric affine transformations. That procedure may also serve to illustrate the second type of the development of procedures, namely its application to the overall procedure itself.

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[1] For a description of the development of actions associating objects with concepts, see Chapter Three. The methodology for other actions is discussed in the dissertation of G. A. Butkin (16) and in the dissertation of M. B. Volovich (18).

In schools the study of geometrical transformations extends over several years; each type included in the programme is studied individually with the help of a particular method that makes it possible to arrive only at the given type of transformations and frequently in a purely mechanical way, since in the procedures given to students only the executive parts of actions are shown. The conditions that indicate the nature of the given geometric transformations and make it possible to understand the logic of executive operations remain unknown. Here, for example, is the manner in which it is proposed to carry out a symmetric transformation of a segment in relation to an axis: 1) at each end of the given segment draw lines that are perpendicular to the symmetry axis; 2) extend these straight lines beyond the axis and on these extensions mark segments that are equal to the distances from the end of the given segment to the symmetry axis; c) connect the points of the resulting segments. We decided to verify the rationality of the actions being carried out by the students. More specifically we asked the following questions of sixth-, seventh-, and eighth-grade students showing good performances: 1) Why should straight lines be drawn from the end points of the segment? 2) Why should they be perpendicular to the symmetry axis? 3) Why is it necessary to draw a perpendicular towards the axis of symmetry? Correct answers to these questions were rare not only among students but also among teachers of mathematics, and even among certain specialists in methodology. Since the actions being carried out by students in effecting geometric transformations possessed neither the needed measure of rationality nor the necessary element of conscious awareness, it is natural that the study of geometric transformations produces considerable difficulties, does not arouse interest among students, and does not contribute to the development of modern geometric thinking.

In view of our appreciation of the decisive importance of an orienting basis of action and of our knowledge of the effect that can be obtained by constructing an orienting basis of action of the third type we sought to apply that method. Together with I. A. Volodarskaya (20) we carried out a corresponding experiment. First, it was necessary to identify the system's invariant underlying all transformations of the given type. An analysis was carried out of such specific affine transformations as movement (rotation around a point, central symmetry, rotation around an axis, axis symmetry, parallel shifts); homothety and similarity (which reduces to homothety and movement). This indicated that the following properties are characteristic of all these transformations: a) their orientation on points, i.e., all transformations translate a point into a point—to each point A of a plane corresponds a specific point A′ into which A is transformed; b) reciprocal uniqueness, i.e., all transformations translate each point into one and only one point and two distinct points are translated into two distinct points; c) in all transformations there exists a rigorously defined ratio of distances between any two points in the initial object and the corresponding points in the final object: it is always equal to a specific coefficient K. For all transformations of movement $K = 1$, in cases of homothety and similarity $K \neq 1$. Moreover, the process associated with all these transformations includes the same components.

1. The initial object of transformation, namely that which is to be transformed; the initial object may be any geometric figure.
2. The object in relation to which the transformation is carried out; this may be a point, a straight line or a plane.
3. In order to effect any of these transformations it is necessary to carry out one of two actions: a) to turn the initial object around a point (axis, plane); b) to shift it to a particular vector—or else to carry out both these actions one after another.
4. The final object of transformation.

The specific features of transformation also determine the components of the procedure employed to carry out all indicated types of transformations. This includes the following components.

1. An analysis of the initial object of transformation in order to identify so-called determining points (a finite number of points that make it possible to recreate the given object).
2. The specification of the object in relation to which the transformation is effected.
3. The selection of the action that will carry out the transformation: rotation (around a point, axis or plane) or shift to a vector.

4. The execution of the selected action.
5. An analysis of the final object.

In addition, a general set of instructions was prepared for the transformations to be carried out and specific instructions for each of the specified components.

The general set of instructions included the following.

1. Specify the initial object of transformation.
2. Specify the object in relation to which the transformation is to be carried out.
3. Identify the determining points for the initial object.
4. Specify the actions with the help of which it is possible to effect the transformation.
5. Select the action that is needed for solving the given problem.
6. Carry out the selected action (the corresponding instructions were given at this point).
7. Specify the final object of the transformation.
8. Compare the initial and final objects.

In order to facilitate the use of the general instructions a special table was constructed in which the students recorded the results of each of the indicated actions as applied to the conditions of their corresponding problem. At the material stage this table indicated the name of each component but at subsequent stages the table gradually became "silent". The executive part of the actions entering into the procedure remained materialized and only the orienting basis of action experienced changes in form.

The group to which the tests were applied consisted of 50 weak and average seventh-grade students.

After the development of the preliminary system of actions and knowledge students initiated a stage-by-stage assimilation of the indicated general procedure. At the stage of the development of materialized actions students worked with models that made it possible to materialize the entire process of transformation and to show its logic. The assignments related to applications of the overall activities procedure. Here is one of the problems: "A triangle ABC is given together with a point O lying outside the triangle. What will be the position of this triangle after it has been rotated around point O through an angle of forty degrees?" After receiving a set of required models and a set of instructions concerning the execution of the transformation students carried out and recorded in a table the specific conditions and actions associated with the given transformation. For example, in the column described as "Initial object of transformation" they wrote: "the triangle ABC"; in the column "Number of determining points of the initial object of transformation" they wrote: "three points, the vertices A, B, C"; and in the column "Selected action" they wrote: "rotation around a point".

In carrying out a transformation the students were able to see the general nature of the components. At the same time as they varied each of these components they arrived at the diversity of specific types of transformation. Naturally, they viewed such types of transformation as rotations around a point and central symmetry not as two different types of transformation but as a common type, differing from each other only in terms of the angle of rotation; similarly, they viewed axis symmetry and central symmetry as differing only with regard to the object in relation to which the transformation was carried out; in the first case it is a straight line while in the second it is a point, etc.

Such a procedure for action clearly differs from the procedure relating to proofs in that it makes it possible for the student to produce himself all specific phenomena in the given area.

Another difference between the procedure of proofs and that of geometric transformations lies in the fact that the first of these is a logical one and as a result may be applied in all areas within which such a type of proof applies, while the procedure that has just been considered is a specific one, which may be applied only to a given field of knowledge.

Indeed, the procedure relating to proofs may be effectively applied to other branches of geometry and other fields of knowledge. The scope of the transferability of that procedure was tested by assigning theorems on parallel lines. First, the concept of parallel lines and of attributes of parallel lines were developed. Then several theorems were given. The students were able to transfer the assimilated procedure to the new material and to prove without help such theorems as the equality of acute (and obtuse) angles with corresponding parallel sides; the parallel character of bisectrices of two acute angles with corresponding parallel sides, etc.

It is true that such a procedure may be employed only in those cases when proofs of the corresponding type are relevant, which call for associating an object specified in problem conditions with a concept indicated in the conclusion, and which are carried out through an inference of the concept attributes from given conditions. (In those cases in which the proof is based on the method of demonstrating the impossibility of a proposed conclusion that procedure is not applicable, even though there, too, the essence of the corresponding procedure lies in associating objects with concepts. The difference is that the process of arriving at proofs by showing that the converse is not possible centres not on a search of attributes of a given concept but on a search of necessary attributes of another opposite concept. Even though the development of the method of arriving at a proof by disproving the converse is not a difficult task once the method that is being examined has been assimilated, it is nevertheless a different procedure calling for the assimilation of certain new actions.)

The given procedure of proofs may be applied effectively in those cases in which it is required to associate an object not with a specified concept but with a particular concept from a system of concepts. In particular, it may be applied effectively in arriving at a diagnosis of illness. In such cases the logical aspect of the reasoning process is exactly the same as in the proof of geometric theorems. This, of course, is not surprising, since the logic of reasoning does not depend on specific contents.

With regard to various possibilities that are acquired with the help of procedures of cognitive activity it should be noted that some of them make it possible to analyze simultaneously and independently specific phenomena from the given area and also construct them. An example is provided by the procedure considered earlier relating to the shaping of parts corresponding to particular forms, which was developed by Z. A. Reshetova and I. P. Kaloshina (74) (Chapter Two). Students who have learned to use that procedure were able not only to analyze independently indicated lathes from the point of view of their applicability for producing parts possessing specified shapes, but were also able to solve the converse problem effectively, namely, to design a diversity of lathes that could produce parts of a specified form.

Another example is provided by the procedure for solving arithmetic problems relating to "processes" that we developed jointly with G. Nikola (109). There are more than 30 types of problems in arithmetic whose solution is based on the analysis of processes: "reservoir problems", "operations problems", "problems relating to movement", etc. In school many of them are assimilated as independent types, and emphasis is given on a system of executive operations. Even in cases in which a situation analysis is carried out this relates to a concrete form of such an analysis as it bears on the conditions of the given problem, such as the fodder that has been expended during the day; the distance covered by a pedestrian during an hour; the water that has leaked out during a minute; etc.

An analysis of these problems shows that they are all based on the same concepts, namely, rate, time, and the outcome that the process either produces or else destroys.

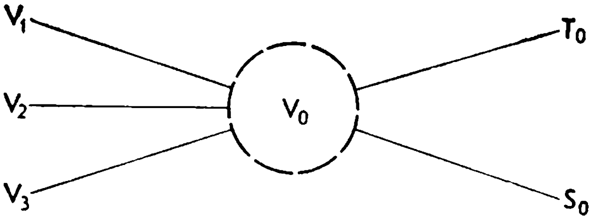
The problem was to develop the general procedure for solving arithmetic problems on processes by constructing an orienting basis of action of the third type. This required that the students be taught to see in each problem those elements that characterize any process (invariant), namely, the process speed (V), its duration (T) and its outcome (S).

Effective solutions of problems of this type require that relations among basic elements of the situation also be understood, namely: a) that the value of the outcome is directly proportional to the speed and time; b) that the time required for obtaining a specific output is directly proportional to its magnitude and inversely proportional to the rate, etc. Next, it is important to assimilate the finding that for any two of these elements it is always possible to identify the third. Finally, in cases in which the outcome is produced by several participants a new system of relations emerges, namely relations among specific and general values of each parameter that are determined by the nature of the participation of individual forces: whether the participants help each other or impede each other, whether they participate in the process simultaneously or at different times, etc. All of these are component elements of the given procedure and constitute a programme of what should be taught in the given case.

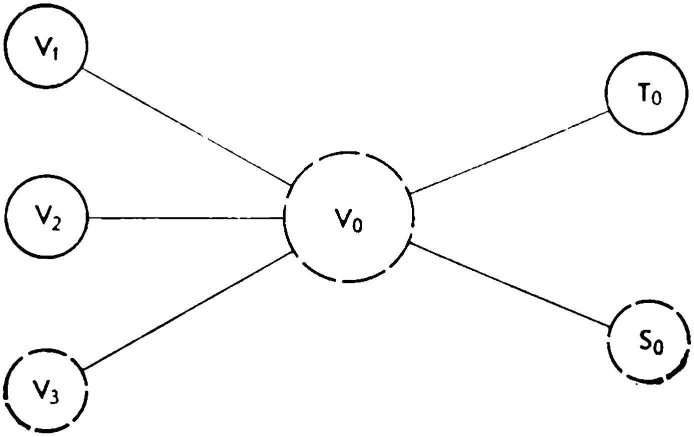
Following a stage-by-stage assimilation of all identified elements, their mutual relations and of the general method of analysis of problem conditions, students were given a method for drawing a diagram representing the situation in question and a plan for arriving at a solution. Initially this was done in relation to a single operating force while later conditions related to joint actions. Subsequently, a general set of instructions was given that made it possible to analyze the problem conditions and to draw corresponding situation diagrams and solution plans.

The instructions call for noting in the problem conditions the participants in the process, and the manner in which they interact (whether they help each other or impede each other), as well as the time of participation of each. This produces a description of problem conditions in terms of a particular system of symbols. Then the students are asked to identify what is to be found and to represent it in terms of the corresponding symbol (V_1, S_1, T_1, V_2, T_2, S_2, etc.) and to circle it with a dotted line.

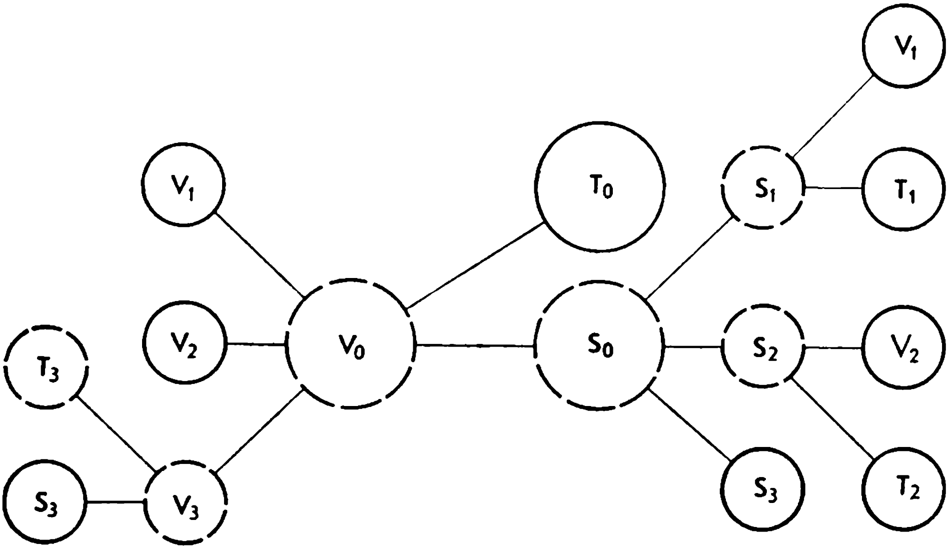
Let us assume that the element that is to be found is the general speed of the process (V_0). It is necessary to indicate the values of attributes that make it possible to find it. Following an assimilation of basic elements and of their relations the student knows that it may be obtained in only two ways: either through the overall time (T_0) and the overall outcome (S_0) or else through the rates of movement of each participant. This is what he represents on Figure 1.



Then the instructions ask him to indicate which of the recorded elements are known and which are not; the student analyzes the problem conditions further and finds, for example, that T_0 is given while S_0 is not, etc. At that point the figure acquires the appearance indicated below (Figure 2):



Then the student must establish whether it is possible to find S_0 or V_3. He knows that S_0 may be found in two ways: from T_0 and from V_0 or from specific values of S. Since in the present case the first approach is not possible (V_0 is unknown) there remains only one other, namely through specific values of S. Thus by analyzing the problem in accordance with instructions the student arrives at Figure 3.



It may be seen from that figure that the path indicated to the right of V_0 leads to a solution, while the other, to the left of V_0, does not (it is impossible to find T_3).

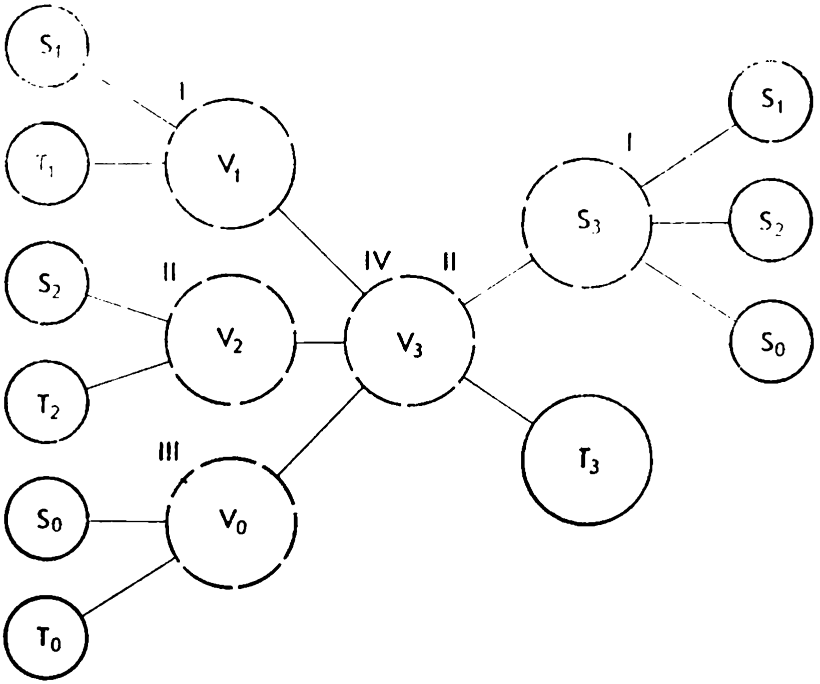
On the basis of such a situation diagram students prepare a solution plan for the problem and carry it out. Executive operations do not pose any difficulties since the students have already assimilated mathematical expressions for the relationships that exist among the situation elements that are represented. This procedure makes it possible for a student to develop a comprehensive orienting basis in solving all problems of this type, thus contributing to an understanding of the given system of relations, and hence to an adequate translation into the language of arithmetic operations.

The representation of the situations specified in problem conditions in terms of figures leads to a transformation of the problem's text into a model that is both visible and abstract, in which all situational relations may be seen simultaneously. It also represents a plan for arriving at a solution: the number of elements within the broken circles show how many questions (and actions) are needed to solve the problem. In moving forward from known magnitudes the required sequence of needed actions may be easily established.

Such a representation also makes it possible to select the most rational solution sequence. Indeed, an analysis of the problem may result in constructing a network that will show that a solution may be obtained both by moving from right to left and in the other direction. But the number of steps may differ in each case. The following is an example of such a problem: "Three machines required 250 litres of fuel over ten hours. It is known that during this time the first machine employed 60 litres and the second 110 litres. Find how much fuel the third machine expended per hour" (see Figure 4).

It may be seen that the path represented on the right-hand side of the unknown element makes it possible to solve the problem in two steps while the path indicated on the left-hand side requires four actions.

Such a method of modelling problems "in terms of processes" permits students to derive a number of specific problems of that type. Indeed, by varying the unknown element and constructing abstract networks of dependences that make its calculation possible students were able to invent any desired large number of different problem situations. Thus, that procedure makes it possible not only to solve all specific problems relating to processes but to design them as well. Moreover, it makes it possible to design a logically consistent system of problems that will encompass all major variations in problem conditions.



Naturally, in modelling cognitive action procedures those problem specifications are first taken into account that have led to the study of the given area of knowledge. In some cases the objective is to carry out an independent analysis of specific phenomena while in others it is to recreate them. Naturally, in cases in which both problems may be solved through a common procedure that procedure should be employed fully since it increases considerably the scope of the student's cognitive abilities.

§ 3. Developing Procedures for Cognitive Activities and Assimilation of Knowledge

The development of activities relating to cognitive procedures is closely related to the assimilation of knowledge. The modelling of the necessary activity procedures, moreover, makes it possible to determine not only the volume and the contents of such knowledge, but also specifications bearing on its quality. For example, the content of a procedure relating to arriving at proofs shows that the actions of association of objects with concepts that it requires, and of inferring consequences, define particular specifications with regard to the development of concepts bearing on the carrying out of proofs. Above all the scope of the concepts being developed should reflect the entire system of essential properties that are employed in arriving at a proof. Beyond this students must be able to differentiate between merely necessary properties and necessary properties that are also sufficient. Third, students must understand the equivalence of certain systems of necessary and sufficient attributes. This is important because the association of objects with concepts can be effected, as was shown earlier, not only by relying on the total set of properties specified in the definition, but also on the basis of their equivalent sets. Fourth, the concepts must possess the attributes of an orientation on systems, i.e., must possess systemic attributes. They must be developed not in isolation from each other but as elements of a system that are related to each other in specific ways. When the newly developed concepts do not possess these properties the action of inferring consequences cannot lead to a positive outcome since it is frequently directed at identifying properties of one concept within the properties of another (for example, one should see in a bisectrix of an angle one of the attributes of a perpendicular) or else at identifying properties that are consequences of interrelations among objects belonging to different concepts specified in the problem conditions.

In its turn the development of both these and certain other properties of concepts calls for the development of a number of underlying actions among students (comparison, hierarchization, and others).

Similarly, the general procedure of effecting geometric transformations that is modelled in terms of all component actions and structural elements makes it possible not only to identify the knowledge required by that procedure, but also to establish that the number of such actions exceeds those that are included in a school programme. It becomes necessary to first provide for the assimilation of such concepts as vectors, direction angles, oriented figures, and equality, which are not studied in school courses on plane geometry, as well as for the assimilation of procedures to draw the objects that correspond to these concepts.

Finally, a modelling of activity procedures makes it possible to identify deviations in applying the principle of consistency in designing school programmes. For example, the procedure for solving process-oriented arithmetic problems has shown that their solution is not possible if students have not assimilated knowledge associated with the fundamental dimensions of processes and their relations. Yet this knowledge is taught only in courses in physics, and even then only in specific contexts, namely in studying motion. In arithmetic, on the other hand, process-oriented problems are given much earlier. Beyond this, they are associated not only with motion but with the most diverse processes.

Thus, as in the case of individual actions, cognitive activity procedures always include specific forms of knowledge that are developed either beforehand, in the process of developing other actions and procedures, or else in connection with the given procedure.

Similarly, as in the case of individual actions, in those cases in which new knowledge enters the structure of similar activity procedures the developmental effect of teaching will be low, and conversely, as the number of activity procedures associated with the development of knowledge increases the students' cognitive activities will also increase.

An application of the regulation principles that follow from the theory of stage-by-stage development of mental actions makes it possible to regulate not only the assimilation of individual cognitive actions but also the development of intellectual activity procedures.

As in the case of individual actions the process of the assimilation of a complex procedure may be carried out properly from the very first. In such a case as well the internal logic of assimilation may be seen in the system of transformations that is experienced by the procedure that is being developed.

All studies concerned with the development of general procedures of cognitive activity were highly effective: first, the corresponding procedures were developed among all students; second, students experienced no difficulties in applying them in new situations and were able to explain the corresponding process, i.e., the procedures were developed as generalized procedures suitable for a conscious and autonomous application in new conditions; third, even though the development of general activity procedures was nearly always associated with the assimilation by students of additional knowledge and actions, the time spent on assimilating the corresponding material was on the whole much less than in a conventional teaching practice (sometimes several times less, but usually 1.5-2 times less).[1]

In this connection it is important to emphasize that a large number of experiments have been carried out on the basis of the theory of stage-by-stage development of mental actions in relation to such subjects as writing (119), reading (187; 189), Russian grammar and the grammar of other languages (2; 61; 104), arithmetic (43; 44; 45; 55; 149; 161), production training (132; 133; 134; 155; 74).

The possibility of applying the theory of stage-by-stage development of cognitive activity has been studied not only at the level of secondary schools but also in teaching pre-school-age children (75; 176; 111) as well as in teaching in high schools (181; 69; 79) and in relation to both individual and group teaching activities (191; 192; 76; 149; 161).

In describing the progressive course of the learning process, P. Ya. Galperin's theory has made it possible for educational psychology to regulate a learning process and has provided means for developing cognitive and other types of activities possessing specified qualities.

Far-reaching prospects have emerged in relation to the practice of teaching as a result of the possibility of regulating the learning process. At the same time this possibility has raised a number of new theoretical problems. The organization of an effectively regulated learning process has shown that it follows a course that differs substantially from cases in which there is no such regulation. The principal difference concerns the following: in the case of effective regulation of the learning process one does not find the wide deviations from a central direction which were formally described as principles that characterize the appearance of any new knowledge and any new skill. Psychologists were not able to see the positive process proceeding behind these greatly diverse deviations and the shifts in its qualitative states. Conversely, the absence of errors produces favourable conditions for studying that problem: in cases in which the assimilation process occurs without errors from the first it is possible to study that process not as a movement away from substantial errors to less substantial ones, but as a process of qualitative changes in an action's basic characteristics that remains constant and free of errors in relation to its subject content. It is precisely under such conditions that it is possible to study the principles that govern the process of knowledge assimilation as a specifically human way of acquiring experience.

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[1] The findings of the corresponding studies have been published in the following collections: *Formirovaniye znanii i umenii na osnove teorii poetapnogo usvoyeniya umstvennykh deistvii* (Developing Knowledge and Abilities on the Basis of the Stage-by-Stage Theory of Assimilating Mental Actions), Moscow State University Press, 1968; *Zavisimost obucheniya ot tipa oriyentirovochnoi deyatelnosti* (The Influence of Types of Orienting Activities on Instruction), Moscow State University Press, 1968; *K probleme upravleniya obucheniyem i vospitaniyem* (A Contribution to the Problem of Regulating Learning and Training), Moscow State University Press, 1970; *Upravleniye poznavatelnoi deyatelnostyu uchashchikhsia* (The Regulation of Student Cognitive Activities), Moscow State University Press, 1972.

The possibility to control the cognitive activity of students on the basis of the theory of stage-by-stage development of mental actions as well as the positive results of its experimental application allow it to be recommended as a psychological basis for programming learning.

Apart from the above-mentioned theory, there are other theories of instruction in psychology, associationist-conditioned reflexes theory, behaviourist theory and Gestalt theory—all of which are reflected in the field of programmed instruction. This calls for necessity to analyze the theories in the light of the requirements formulated in Chapter One of the present work. Since even the supporters of Gestalt theory do not consider it capable of forming an independent psychological basis of programmed instruction, [1] we will confine our studies to examining the first two theories, i.e., the associative-conditioned reflexes theory elaborated by Soviet psychologists and behaviourism developed by US scholars.

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[1] J. Martens, a representative of Gestalt psychology, wrote: "It is not the point whether we should develop programmed instruction on the basis of the theory of associationist (behaviourist) psychology or should not. The point is that Gestalt psychology may play some supplemental role as programmed instructions" (267).

Chapter Five

ASSOCIATIONIST-CONDITIONED REFLEXES THEORY AS A BASIS FOR PROGRAMMED INSTRUCTION

The authors of that theory, namely Bogoyavlensky, Menchinskaya and Samarin, share the principles of Soviet psychology that have been described. As the principal basis of the theory of learning, however, they rely on the propositions of I. M. Sechenov and I. P. Pavlov. We do not propose to analyze the experimental studies of these authors. Rather we will limit ourselves to an analysis of the theory itself, above all from the point of view of the possibility of applying it in order to control the teaching-learning process. First, however, we will say a few words about associationist theory, since it would otherwise be difficult to analyze the associationist-conditioned reflexes theories that concern us.

§ 1. The General Characteristics of the Associationist Theory

In the literature on programmed instruction associationist theory is sometimes related to Pavlov's conditioned reflexes theory (9). In this connection it is important, first, to note that one should not confuse the phenomenon of association with a psychological associationist theory that provides a specific explanation for the emergence and operation of associations. Second, the theory of Pavlov is essentially anti-associationist.

The phenomenon of associations has been known since the time of Aristotle, who was the first to classify them. The fact itself of associations (linkages) of individual phenomena in psychic activity cannot be doubted. One of the laws of dialectical materialism is the law of general linkages and relations; in the external objective world everything is linked and mutually conditioned and since psychic activity is a reflection of that world it contains not only images of objects and phenomena from the external world but also reflections of their linkages and relations.

The concept an "association" is present in the works of Pavlov, who studied the conditions and physiological mechanisms that bear on the development and functioning of neural linkages that make possible relations between an organism and its environment. He employs that term either as a synonym for such concepts as temporary connections and conditioned reflex (115) or as a generic concept in relation to conditioned reflexes (116).

Associationist theory appeared in the eighteenth century. It was initially formulated by a materialist English doctor of medicine, David Hartley (285). At the time when it was written that theory was progressive. D. Hartley based his theory on two elements, namely, feelings (the simplest psychological element) and the affective tone that is combined with experienced feelings. All phenomena in psychic life consist of these two elements. The mechanism underlying all psychic phenomena is associations and vibrations. Associations are the outcome of vibrations being disseminated within the brain: two influences on the brain form two centres of origin from which vibrations proceed along neural paths. It is the linking of these vibrations that leads to images of objects and of phenomena of the outside world that influence sensory organs. In this way the linkage of psychic phenomena or association is the outcome of a physical process of vibrations that are being disseminated along neural tissues. This was a materialistic but highly mechanistic theory.

Associationist theory remained influential in psychology up to the twentieth century. It experienced a number of changes; and within it, aside from materialist branches, idealistic branches developed as well. Within the materialist branches of associationism the principle of vibrations was replaced by the principle of resonance, by an energy-related principle, and by others. But in spite of all changes the following mechanism remained characteristic for associationist theory: a) different psychic phenomena are inevitably viewed not as qualitatively distinct but merely as different external combinations of the same initial elements; b) according to that theory psychic phenomena are viewed as having appeared independently of the subject's activities and without considering his needs and the problems that he confronts. In other words, associationism neglects the subject's activities which are a necessary condition for the formation of any psychic phenomenon and any association. It considers that in order for associations to appear it is sufficient that actions of stimuli be experienced (simultaneously or in sequence). Everything else is explained by the flexibility of the brain, and its ability to filter and retain traces arising under the influence of stimuli. Psychic phenomena are thus merely shadows of processes taking place in the brain while the subject of reflection is a passive element: his brain records mechanically everything that it experiences.

The inconsistency of associationist theory became apparent already in the nineteenth century. In particular, a sufficient number of facts was accumulated already at that time indicating that different psychic phenomena possess specific qualitative features that cannot be reduced to qualities of component elements.

The studies of I. M. Sechenov and I. P. Pavlov have shown that the brain does not operate in a mechanistic manner and that its flexibility expresses itself not in its retention of traces of all influences to which it is exposed, but on the contrary, in a very great selectivity in relation to them. This selectivity is determined by a system of real relations between the organism and its environment. In order that a nervous linkage be formed within the brain a mere coincidence of stimuli is not sufficient; first, the subject must also possess a need (dominant, optimal centre of excitation); second, one of the active stimuli must be significant and must respond to existing needs. In other words, in order that a particular association develop it is necessary that it possess a significance for the person and a definite meaning; associations that have lost their vital significance are destroyed and are made passive. Finally, the reflection in the brain of an objective relation between operating stimuli may occur only when the subject identifies that relation, i.e., executes a specific orienting activity that is directed at these stimuli (orienting reflexes).

It is in the light of these considerations that the inconsistency of the associationist theory was shown. The studies of Pavlov and of his associates have shown that it is not possible to understand and describe correctly the mechanism of neural linkages if one disconnects the subject from his system of real relations to his environment, without considering his needs and the problems that he confronts, without analyzing those of his activities that are directed at objects and phenomena in the external world.

Accordingly, the theory of Pavlov by no means confirms the correctness of the old interpretation of an association and of the mechanistic associationist theory that has been developed on that basis. On the contrary, it calls for a basic reconsideration of that concept as well as of the entire theory. S. L. Rubinstein is fully correct in writing that "Pavlov's interpretation of conditioned relations does not provide a basis for the old understanding of associations". He continues: "In order to carry out a 'fusion' of a conditioned relation with associations or else superimpose associations on conditioned relations a radical transformation of the old concept of association is in fact required, together with the development of a new associationist theory" (143, p. 211).

It follows from what has been stated that associationist theory represents a past stage in the development of psychology. Yet that long obsolete theory has been resurrected twice during the past quarter century. Initially, this occurred following the widely-known conference on Pavlov's theory at which the problem of developing a conditioned reflexes approach to psychic activities was formulated together with the problem of establishing a closer relation between the physiology of higher nervous activity and psychology. At that time instead of a creative application of Pavlov's anti-associationist theory to solving these problems of psychology some psychologists began to revive the old associationist theory. This has already been noted in the literature on psychology (188; 65).

The second time associationist theory was revived in our country in connection with the appearance of the idea of programmed instruction. Its application to programmed instruction was advocated by Samarin, Esaulov, and a number of other authors (e.g., 153; 154; 9).

Thus, in recognizing the existence of associations we are categorically opposed to their associationist interpretation as well as, of course, to that theory as a whole. Let us now consider the principal object with which we are concerned.

§ 2. The General Features of Two Types of the Associationist-Conditioned Reflexes Theory

The associationist-conditioned reflexes theory is presented in the works of Samarin (152), Bogoyavlensky and Menchinskaya (14). In these studies it is stated that the key concept in analyzing psychic activity is association. In particular, Bogoyavlensky and Menchinskaya write, "We assume that the basic simplest element of the cognitive process is association and that the basic task in our research is to study the way in which associations and systems of associations develop under teaching conditions" (*Ibid.*, pp. 11-12). Samarin considers that the analytical unit in psychology is the feeling (of external events). "All complex psychic processes—perceptions, representations, thought, feelings, etc.—are based on feelings (of external events) and on corresponding traces" (*Ibid.*, pp. 216-17). Samarin used association as a mechanism of psychic activity: "Associations are linkages of psychic processes ranging from the simplest to the most complex ones" (*Ibid.*, p. 383).

It is not possible to agree with any of these assertions. In choosing a unit for purposes of psychological analysis it cannot be forgotten that the psyche must be viewed as an activity of the subject for only such an approach to the study of psychic phenomena makes it possible to overcome the epiphenomenalism of empirical psychology, including its associationist branch. By viewing the psyche as one of the types of human activity that links the person with the external world and regulates the external world's relations with him makes it possible to understand correctly both the psyche's function and its genesis. In the logic of empirical psychology the psyche is a subjective phenomenon contained within the subject and separated from his real life and having appeared for reasons that are not understood. In the logic of Marxist psychology the psyche is a natural stage in the development of life itself which makes it possible for the subject not only to regulate his behaviour in the external world but, on the level of man, to transform that world.

The view that the psyche is a type of activity requires that it be analyzed as has been noted in units of activity.

Otherwise the subject as an active element will vanish from view and the recognition of the psyche as a specific type of activity will remain an empty declaration. This is precisely what has occurred in the studies being considered. The authors speak repeatedly concerning the unity of the psyche and of human activities and state that the psyche is a form of activity. But in the context of a concrete analysis of psychic phenomena these propositions are not applied and cannot be applied in terms of the units of analysis that have been specified. Indeed, the view that feelings (of the external world) are analytical units of the psyche and that associations are mechanisms of psychic phenomena implies a reduction of the psyche to chains of images. The entire operational aspect of psychic activity through which a subject's activity is realized remains neglected.

Nor does the situation improve when an association is taken as a psyche's analytical unit. In their book, Bogoyavlensky and Menchinskaya do not show how the unit that they select may be employed in analyzing psychic activity and why this particular unit must be selected rather than another. It may be seen from a subsequent exposition that the authors interpret an association as a concept that is identical with the concepts of conditioned reflex and temporary connection. It is well known however that Pavlov viewed conditioned reflex and temporary connections as units in the physiological analysis of higher nervous activity. A failure to differentiate psychological units of analysis from physiological ones has caused Bogoyavlensky and Menchinskaya to substitute physiology for psychology and to abandon an analysis of specific psychological principles of behaviour that follow from the structure and contents of those forms of human activities that are directed at the external world.

Nor can one accept the view that associations are mechanisms of psychic activity. This view proposed by Samarin is not proved in any way and we agree fully with Rubinstein who writes, "Associations are generally not so much 'mechanisms' as a fundamental phenomenon that itself calls for explanation and for an identification of its mechanisms" (146, p. 156). In order to understand why particular associations developed it is necessary to analyze the content and structure of that activity of the subject whose outcome and product such associations represent. A simple observation that various types of associations exist does not explain their emergence and does not identify the principles that govern psychic activity.

Advocates of the associationist-conditioned reflexes theory recognize the inconsistency of the old associationist theory and call for the development of a new one that would be based on Sechenov-Pavlov's theory of reflexes. In order to develop a new theory it is necessary first to identify the shortcomings of the old associationism. This, however, has not been fully achieved in the works under consideration. Thus, for example, Bogoyavlensky and Menchinskaya while correctly noting that advocates of associationism interpret the development of association mechanistically, without considering the subject's activity, find that the shortcomings of associationism is that its advocates supposedly "interpreted associations as a linkage between psychic phenomena, viewing them outside the context of the problem of material causality" (14, p. 12). This assertion does not correspond to the facts. Beginning with D. Hartley all representatives of the materialist branch of associationism attributed the emergence of associations as linkages among psychic phenomena to the brain's presumed capacity to respond to externally originating influences and to retain their traces. It is another matter that such an approach to establishing the causality of psychic phenomena is naively mechanistic and accordingly invalid.

Samarin considers that the flaw in the old form of associationism is merely that it does not see the qualitatively specific features that attach to transitions from perception to representations and from representations to concepts. It is surprising, however, that he himself then adds that concepts develop from representations and reasoning is an association of concepts (152, pp. 190-91).

An incomplete and logically inconsistent analysis of the shortcomings of the associationist theory hinders Samarin's attempts to identify the fundamentally new element that the Sechenov-Pavlov theory of reflexes contributes to the understanding of the psyche and the concept of an association. As a result instead of presenting a new approach to the analysis of psychic phenomena on the basis of the theory of conditioned reflexes, he reconstitutes the old classical associationism.

Let us begin with an analysis of Samarin's interpretation of the concept "association" itself and of its relation to the concepts "conditioned reflex" and "temporary connection".

Samarin views associations as a psychological equivalent of a temporary connection (*Ibid.*, p. 188). In his view an association is a specific type of connection that characterizes the linkage of psychic processes. He writes: "The theory of Pavlov has defined the material foundations of that linkage and the principles that govern its functioning" (*Ibid.*, p. 194). "The material substratum of associations is provided by temporary neural connections established in the cortex of the brain" (*Ibid.*, p. 383).

It is apparent that such an interpretation of associations has nothing in common with the theory of conditioned reflexes and is a typical associationist approach. Under such an approach the principles of conditioned reflexes governing higher nervous activities do not at all influence the association of psychic phenomena and merely relate to its material foundations. Associations for their part are the psychological equivalents of these material foundations, i.e., equivalents of the brain's physiological processes. Such an interpretation of the relation of psychic to physiological processes is a typically parallelist one. In this connection Rubinstein writes: "This is a restoration of the old configuration which is simultaneously mechanistic and idealistic" (143, p. 225). He adds that in terms of its external appearance the characteristics of physiological principles of behaviour bearing on higher nervous activities constituting the material "basis" of psychology seem to be similar to what is a correct understanding of the relation of physiological principles of behaviour bearing on higher nervous activities to psychology. "But in terms of their internal meaning and of their actual direction they express a pronounced dualism" (*Ibid.*). The view of psychic activity on the basis of the conditioned reflexes theory implies that associations must be viewed simultaneously both as a physiological and as a psychological process and implies that principles of behaviour bearing on higher nervous activities must be extended *to psychic processes themselves* and not merely to their material foundations. Phenomena that are psychic in terms of the form of their existence are always material and always represent a specific physiological process that is governed by all principles governing higher nervous activity. The ideal nature of psychic processes is apparent in the context of the relation of the psychic to the external world and not in the context of its relations to the brain. Psychic phenomena represent one of the forms of conditioned reflexes activities. The specific characteristics of "psychic reflexes" lie in that the corresponding responses are neither movements nor secretions but images and reflections of the external world.[1] That image, however, while it is ideal in relation to the object whose reflection it represents, also exists as a material physiological process in the brain, rather than "entering" into a reflex as something that is not material and that disrupts the material continuity of the brain's activity on the basis of reflexes. It is only by recognizing this that one can avoid a substantialist approach to the understanding of psychic processes and its separation from the brain's material nervous processes.

Samarin's acceptance of the old invalid interpretation of an association makes it difficult for him to avoid the following error: in his monograph he writes explicitly that "psychic processes are a necessary link in a reflex" (152, p. 383). Thus it would appear that the psyche is not at all an activity of the brain on the basis of reflexes but merely its "psychological equivalent" and its "link".

Samarin's incorrect interpretation of associations leads not only to a separation of psychic processes from physiological ones but also to a separation of psychic processes from the subject's activities and to its disconnection from the system of man's actual relations with the external world.

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[1] In psychological literature psychic processes are often viewed not as a full reflex but as merely a "middle link" of a reflex or as two thirds of a reflex. In this connection the position of I. M. Sechenov is cited who did in fact interpret thinking and psychic processes in this way. It should be noted, however, that Sechenov asserted this in analyzing the behaviour of man as a whole and in considering the mutual relations of a subject with the world at the level of a macro-approach. The subsequent development of the theory of reflexes, particularly in the studies of recent decades, have shown that when subjected to a micro-analysis already the initial link of a reflex, namely, the perception of a stimulus, constitutes a complex system of complete reflexes (160). Accordingly, psychic processes are not a "fragment" of a reflex but a complete reflex that is usually the outcome of an entire system of different reflexes. Ultimately, however, psychic activity is never the last link in a subject's interaction with the world. It plays an orienting role in relation to man's practical activities in the world. In this sense it is indeed a "middle link".

For Pavlov a conditioned reflex (association) is a relation between a subject and the external world. For Samarin an association is a linkage among subjective images in the form in which they appear to our consciousness. He does not deny his agreement with associationists and writes explicitly that "it is difficult to object to the associationist interpretation of thinking". Samarin, too, sees the essence of thought processes in the view that aside from activating old associations they also develop new ones (*Ibid.*, p. 193). In another study (151) he reduces the entire process of developing new acts of psychic activities to the development of different modes of association among external feelings.

The application of the theory of reflexes to psychic activity means above all an overcoming of the view that the psyche is a closed sphere within the subject and the recognition that it is a real relation between a subject and object. Samarin, whether he wishes this or not, in fact proposes that we return to the old empirical psychology and engage in a fruitless epiphenomenalistic description of psychic phenomena. Under such an approach a neglect of specifically psychological principles is quite natural and this is what has in fact occurred in the works of Samarin. Psychology is expected to merely describe different types of associations that link the final outcomes of psychic (reflexes) activity. As for the principles governing the development of these associations they belong to the sphere of the physiology of higher nervous activity. Samarin notes that the theory of Pavlov has identified the principles governing the functioning of associations (*Ibid.*, p. 194) which are, in the view of Samarin, psychological equivalents of temporary linkages. He adds that the principles governing higher nervous activity have made it possible to explain on a materialistic basis the very essence of the principles governing associations (*Ibid.*, p. 107).

In describing the mechanism of mental activity Samarin writes: "One may point to three psychological mechanisms that derive their physiological explanation in the theory of I. P. Pavlov: associations by proximity (the closing of a connection) and their dissociation; associations in terms of similarity (the generalization of conditioned connections) and their dissociation; and associations in terms of contrast (in accordance with the law of induction and as a result of shifts in phase states) and their dissociation" (*Ibid.*, p. 408).

Samarin refers to psychological mechanisms, yet instead of actually analyzing them he merely lists types of associations. Such a listing of these associations as phenomena and facts of mental activity does not identify any psychological mechanisms nor does it describe psychologically the fact that these associations appear. Accordingly, at the psychological level we only find a recording of certain facts. They are then explained in a purely physiological term. Thus, Samarin's selection of (external) feelings as the unit of psychological analysis and his consideration of associations, in the spirit of the old teachings of associationism, as a mechanism of psychic phenomena unavoidably leads to an interpretation of the psyche as a chain of images and to a neglect of its operational aspect as well as to a failure to recognize the psyche as an activity. At the same time it also leads to a rejection of the theory of reflexes since its principles of functioning are not applicable to the psyche: Samarin extended the sphere of their activity only to the "material foundations of the psyche". As for psychology, it finds itself altogether deprived of any principles and its task appears as the description of different types of associations.

We find a similar approach to the psyche and to psychology in the work of Bogoyavlensky and Menchinskaya. Unlike Samarin they do not view the distinction between an association and a temporary connection as a distinction between psychological and physiological phenomena. As has already been noted they recognize the identity of these concepts. But they view all principles governing psychic activity in terms of principles governing the dynamics of neural processes. In fact, however, as P. I. Zinchenko correctly observes "associations (temporary connections) together with the internal principles governing the dynamics of neural processes which conditions their formation are determined by the subject's activity which in turn is determined by objective reality and the material conditions of that activity" (65, p. 162). But Bogoyavlensky and Menchinskaya do not carry out a concrete analysis of the activities of the subject that relate to the external world. In pointing to individual psychological facts instead of clarifying the specific features that attach to the structure and content of activities leading to these facts they simply refer to general principles governing higher nervous activity. Thus, for example, in analyzing cognitive activities they view analysis and synthesis as primary processes, "as the basic activity of the nervous system" (14, p. 56). At the same time they view the basic stages of higher nervous activity, namely, the initial generalization, differentiation, higher analysis, as the major stages in the development of mental activity.

Naturally, such a reference to general principles governing higher nervous activity does not permit the authors to reveal the actual causes of psychological facts since as these authors recognize the relation between the two is nonunique. For example, Bogoyavlensky and Menchinskaya write: "The irradiation-like process of excitation operates as a physiological basis for the synthetic act of thinking which leads to generalizations." At the same time they admit that the nature of such generalizations may vary: in some cases generalization proceeds along nonessential attributes, and "does not encompass the essence of phenomena"; while in others, it is based on a separation of essential attributes from nonessential ones. Bogoyavlensky and Menchinskaya recognize that in terms of their origins and of their structure these generalizations are psychologically distinct (*Ibid.*, pp. 56-57). As we see generalization itself does not explain anything: it may take place in either of these two cases. But in order to understand why in one case generalization leads to formation of a false concept while in another to the true one it is necessary to move to a wider context than that of connections within the brain and to turn to an analysis of that particular activity which links students with objects that are subjected to concept generalizations. In turning to physiology for an explanation it is not difficult to recognize one of the characteristic traits of the old associationism.

This analysis shows that the authors of the associationist-conditioned reflexes theory have not overcome the shortcomings that attach to associationist theory. This expresses itself concretely in the following propositions whose importance is fundamental: first, associations are viewed either as a linkage between psychic phenomena (Samarin) or as a neural connection and as a purely physiological phenomenon within the brain (Bogoyavlensky, Menchinskaya). Second, in both cases associations are separated from the nature of actual interactions between a subject and objects within the world. The dependence of the formation of associations and of their specific features on the nature of the subject's activities that link him with the external world is not shown. As a result associations appear not as a fact pertaining to a real interaction between the subject and the world but only as a phenomenon that is limited either to the subject's consciousness or to internal activities within the brain. Psychology can then only describe the associations while their explanation lies in the internal dynamics of neural processes.

It is true that at the level of general statements Bogoyavlensky, Menchinskaya and Samarin frequently point to the need to consider the activities of the subject in order to understand the specific characteristics of his psyche. In addition, Bogoyavlensky and Menchinskaya note towards the end of their book that until now the analysis and organization of the teaching-learning process have emphasized activities of teachers and have given an insufficient emphasis to the activities of students (*Ibid.*, p. 332). Their explanations of specific psychological facts that they mentioned, however, are not based on a concrete analysis of the activities of students and as a result of this the corresponding psychology becomes abstract. It is expected to merely record and describe different types of phenomena which are then explained by the physiology of higher nervous activities.

It is widely known that the principles governing the lower "floors" of science also apply to the higher "floors" without encompassing all the principles that govern the latter (223). It should also be emphasized that it is the specific principles governing each area that play a leading role as Rubinstein rightly notes (145).

Thus, from a general psychological point of view the conception that is proposed embodies an associationist rather than a conditioned reflexes theory.

§ 3. The Process of Assimilation in the Light of Associationist-Conditioned Reflexes Theory

An analysis of the learning process that is carried out in the light of that theory possesses the same shortcomings. Bogoyavlensky and Menchinskaya view associations as the basic element of the assimilation process. They consider the task of analysis to be the manner in which associations and systems of associations develop in the process of learning. They consider analysis and synthesis to be leading processes in cognitive activities. An analysis is viewed as any division, disconnection while synthesis as a connection, combination. Neither analysis nor synthesis, however, are demonstrated to be cognitive actions. Their characterization reduces to separations and linkages, i.e., relates to the logical level of analysis.

Much importance is also given to abstraction and generalization but they are viewed as derivative phenomena in relation to analysis and synthesis. Following Vygotsky the authors include abstraction and generalization together with systematization as indicators in terms of which they propose to trace changes in the thought activities of students. But since thought activities themselves are not analyzed as an activity the position that these phenomena occupy in a system of activities remains unclear: whether it is a structural position (as a system of actions) or it is that of basic characteristics of thought activities. Subsequently, in characterizing the stages of assimilation, Bogoyavlensky and Menchinskaya do not show the qualitative changes that take place in analysis and synthesis as well as in generalization, abstraction, and systematization.

The authors note that the differences in the "character of thought operations influencing the development of associations and of systems of associations is reflected in the *composition* of associations and leads to the elaboration of linkages of various types" (14, p. 17). Unfortunately, this correct proposition is not applied to the analysis of the process of assimilation. The authors do not show the way in which specific characteristics of the activities of students influence the associations that develop. Moreover, since Menchinskaya and Bogoyavlensky do not carry out any concrete analysis of the cognitive activities of students that lead to the assimilation of knowledge and to the development of specific associations, there is no psychological analysis of the *process* of assimilation. It is true that the authors refer to stages of assimilation and even to principles "that help identify the essence of transitions from lower stages of assimilation to higher ones" (*Ibid.,* p. 16). But first they distinguish the stages of assimilation not in terms of qualitative changes that are experienced by the characteristics and leading processes of cognitive activity but in terms of the *outcomes and results of an activity that remains unknown.* Second, in referring to the principles that govern the essential aspects of the transitions in assimilation from lower stages to higher ones, it is physiological principles relating to the analytical and synthetic activities of the brain that are considered.

At initial stages the leading processes of cognitive activities, namely analysis and synthesis, are represented as simply elements without any systemic structure. One of the following two specific features are found among students that are at that stage of assimilation: instead of distinguishing a system of attributes on which to orient themselves in their activities they identify only one which for some particular reason appears as "stronger" than the others from the point of view of students or else they master a number of attributes but these attributes are assimilated in some arbitrary sequence, without distinguishing essential attributes from the nonessential ones and without understanding the dependence of some attributes on others. Menchinskaya and Bogoyavlensky explain the first of these cases in terms of a dominance of synthesis over analysis and the second, conversely, in terms of a dominance of analysis over synthesis (*Ibid.,* p. 57). At the same time, it is stated that both cases are manifestations of the law of irradiation. Since generalizations take place in relation to specific elements of concepts being studied the authors call it *intraconceptual.*

Similarly, the phenomenon that Bogoyavlensky and Menchinskaya call *interconceptual* generalizations also relates to that stage of assimilation: "The facts and phenomena relating to one concept become involved into the sphere of action of another concept" (*Ibid.,* p. 65). As in the case of intraconceptual generalizations the authors identified two cases of interconceptual generalizations. In the first group generalizations occur under conditions in which one of the rules be studied in isolation from others by students who are unfamiliar with other "competing" rules. In the second case all necessary elements of knowledge are known to students but the "critical" examples are preceded by exercises in terms of a familiar rule or else variants of familiar rules clash in the course of exercises and generalization is produced by the frequency of repetition of one of these variants.

Thus, the first stage of assimilation of knowledge is characterized by various types of errors. These errors are attributed to purely physiological causes: namely, the operation of the law of irradiation. It remains unknown why generalizations of that level proceed in terms of nonessential attributes rather than essential ones which are inevitably present in the data. In order to understand this it is necessary to turn to an analysis of the cognitive activity of students and to its content and structure, i.e., to move from general physiological laws to laws that are specifically psychological. The authors, however, do not do this. They merely record the very modest outcomes of such activities. The observation that in one case synthesis prevails over analysis and in the other case the converse is true is too general. It is again an observation of results of analytical and synthetic activities rather than an identification of the specific contents and specific features of those acts of analysis and synthesis that bring students to the corresponding results.

Bogoyavlensky and Menchinskaya describe the subsequent stages of assimilation in a similar way. This refers to stages in which synthesis and analysis begin to correspond to each other and acquire a systemic character. The overall process of development of analytical and synthetic activities is represented by the authors in the following way: at first synthesis is not supported by corresponding forms of analysis—the latter lags and appears in insufficiently refined forms. At the next stage, on the contrary, synthesis lags behind analysis. And finally, at the last stage they come into correspondence with each other. In this connection it should be noted that in some cases the authors combine the first two stages into one (*ibid.*, p. 68) while in others they view them as distinct processes (*Ibid.*, pp. 57, 74 et seq.). As we see the process of assimilation is not identified in terms of qualitative changes in the cognitive activities of students and does not acquire a single positive attribute. Instead the results of deviations of that unknown process are noted: the types of errors that replaced each other are described. Gradually all errors vanish that finally leads to a correct analytical and synthetic activity. The question naturally arises concerning the way in which this takes place. Bogoyavlensky and Menchinskaya do not identify the psychological mechanism relating to that transition and cannot do this since they do not analyze the activities themselves that the students carry out.

In their opinion the thought activities of students evolve in two directions. First, a further *differentiation* of knowledge occurs and in the course of that process an identification of essential aspects occurs. That process is called a process of differentiation of knowledge. Second, there occurs a systematization of knowledge which is expressed in a combining and generalizing of attributes within a concept or else a number of related concepts that until then had been viewed as distinct. They call that process the *systematization* of knowledge and it is viewed as occurring on the basis of differentiation.

The differentiation of knowledge leads to a gradual replacement of individual associations by "multiple" associations which make it possible to respond in different ways to a given signal or else to respond to different signals in terms of a single action. Systematization also refers to the establishment of different associations, namely, in terms of attributes such as genus, species, causal relations, time relations, etc. A correct differentiation and systematization occur gradually through a number of characteristic errors. Thus, before a correct hierarchical relation of concepts within a system is established a replacement takes place of the types of concepts that enter into that system: general concepts begin to be viewed by students as specific and specific ones are viewed together with general concepts.

On the basis of these facts Bogoyavlensky and Menchinskaya conclude that the process of assimilating a system of concepts embodies the same general principle as the assimilation of an individual concept. But while in the last case errors are associated with difficulties in assimilating linkages between individual concept attributes, in the case of the assimilation of systems of concepts the corresponding difficulties relate to linkages among concepts. A "reduction" of the corresponding process takes place at the concluding stages of the development of analysis and synthesis, individual operations cease to be perceived consciously and are automated. There occurs a development of stereotypes.

This in fact is the full characterization of the process of assimilation of knowledge. It has already been noted that the process of assimilation itself is in fact completely neglected. The cognitive activities of students which constitute the essence of that process remain unknown. Associations are always merely outcomes of particular cognitive activities, or their products. One does not see in these associations the process that leads to their development. This is why the choice of associations as a unit of analysis of the process of assimilation is incorrect. It makes impossible an analysis of assimilation both as a process and as a sequence of qualitatively specific stages in the cognitive activities of students.

Not only do Bogoyavlensky and Menchinskaya fail to identify the assimilation process itself but they do not describe its principal stages in terms of their outcomes either. They only analyze the outcomes of individual deviations of the assimilation process from a correct course. Naturally, errors do represent a definite interest but it is not possible to replace through various types of errors the natural course of that process itself. The authors themselves seem to be aware of this. They write: "It may be assumed that the difficulties that we have described in the assimilation of new knowledge and identification of their psychological causes will make it possible to develop a methodology of learning that will increase substantially the quality of learning by anticipating possibilities of deviations in the analytical and synthetic activities of students from the correct course" (*Ibid.,* p. 96). We thus see that the authors are aware that the stages that they envisage do not identify the course of the process of assimilation ("its correct course"), but merely record the outcomes of deviations from that course and leave the process itself unknown.

Beyond this Bogoyavlensky and Menchinskaya eventually also admit that the stages that they identify do not at all represent necessary stages. Following the description of the stages of assimilation that they identify they note: "The stages of development in analytical and synthetic activities of students that we have sketched could not be viewed as either universal or unchangeable." Subsequently, they recognize that a gradual methodologically correct accumulation of knowledge leads to a situation in which, for a part of the students who were better prepared, the stage of initial generalization is either absent altogether or present in an initial form (*Ibid.,* p. 95).

Thus, the authors recognize that the assimilation of knowledge need not have passed through a number of different errors and that analytical and synthetic activities may be comprehensively developed from the first. And we fully agree with this. This does not eliminate, of course, the need to trace the process of assimilation and to identify its qualitatively specific stages. Moreover, it is only through a reliance on a correct process of assimilation free of errors that makes it possible to approach the study of its natural stages which identify the internal logic of the process.

Finally, in explaining the facts that they cite, the authors merely refer to general physiological principles. This makes it impossible to study the logic of the process of assimilation or to understand the psychological causes for the deviations that occur in its course.

Bogoyavlensky and Menchinskaya actually recognize themselves that the stages that they have identified and that the general physiological principles on which they have relied in explaining the stages do not identify the psychologically specific features of assimilation which must, however, be understood in order to regulate the process of assimilation and to keep it on a correct course from beginning to end. In concluding their description of stages of assimilation they write: "There will be even greater possibilities for making use of psychological data when the psychological conditions will have been studied that are needed for developing correct knowledge and its effective application" (*Ibid.,* p. 96). Thus, they recognize that the stages of assimilation that they have noted lie outside the psychological conditions that relate to the organization of a comprehensive assimilation of knowledge and in this connection they seek to list a number of such conditions. These include the following:

1) the influence of past experience on the course of assimilation; in some cases this may be positive and in other negative;

2) a correct organization of comparisons in the course of learning;

3) the development of forms of motivation among students that correspond adequately to learning objectives;

4) an activization of the student's cognitive activities.

Unquestionably, all these factors do influence the course of the process of assimilation but they do not identify its nature. The number of such factors may easily be increased. A knowledge of these factors, however, when not related to the internal logic of the process of assimilation, does not provide a basis for regulating its course and organizing a process of learning in such a way that these conditions may influence the assimilation only in a positive manner.

Thus, this particular variant of associationist-conditioned reflexes theory cannot serve as a fruitful psychological basis for programming the learning process: the theory that has been considered does not identify the psychological specific features of the process of assimilation but merely points to the outcomes of some of the possible deviations and notes a number of factors that influence that process.

Let us now turn to the associationist-conditioned reflexes theory of learning proposed by Samarin (152). The problem that the author wishes to solve with the help of a particular conception of learning he proposes is how to "identify even in a schematic way certain stages in the development of knowledge and thus in the student's mental development in the sense of a transition from individual associations and partial associative systems to increasingly more generalized associative systems" (*Ibid.*, p. 388). First, let us note that the stages in the development of mental activities may not be reduced to stages in the development of knowledge: for as in the case of any other psychic activity mental activities include a specific system of actions on the part of the subject. Beyond this, the process of development of particular types of associations as well as the process of their transition to a subsequent stage can be understood in terms of its specifically psychological manifestations only through an analysis of those subject's actions that are directed at the particular objects in relation to which he wishes to acquire knowledge. As in the case of

Bogoyavlensky and Menchinskaya, however, Samarin does not analyze that aspect of mental activity. The stages that he identifies do not correspond to the stages noted by Bogoyavlensky and Menchinskaya. As has already been noted, the latter relate these stages to the analytical and synthetic activities of the brain. Samarin correctly notes that Bogoyavlensky and Menchinskaya view analysis and synthesis in a purely physiological way and that they do not identify the psychological nature of that process (*Ibid.*, p. 206).

Samarin also opposes the substitution of a psychological analysis by a physiological one in his analysis of the conception of thinking proposed by Rubinstein. Like Bogoyavlensky and Menchinskaya, Rubinstein considers analysis and synthesis to constitute the principal processes in thinking (144). Samarin observes correctly that "when we say that a decisive role is played by analysis and synthesis we do not yet say anything and do not identify anything" (152, p. 182). With regard to the principles that govern analytical processes Rubinstein points to the "law of primary irradiation and subsequent concentration through analysis" (144, p. 31). Samarin is entirely right in noting that this does not yet constitute a psychological characterization. Thus, Samarin is opposed to the replacement of psychology by physiology and supports the need to identify the specifically psychological features of principles governing assimilation and the contents of thought activities. In his view, however, one should search for these elements in associations which are psychological equivalents of the physiological concept of "temporary connections".

In Samarin's view associations identify the mutual interconnections between representations and concepts and the new ways in which they are combined and in this way make it possible to understand the essence of the process of thinking (152, pp. 187-88). In his opinion the understanding of the association structure of mental activities also represents a decisive element in the analysis of the assimilation process. Accordingly, he differentiates the stages of that process according to types of associations that students develop. Yet a simple description of developed associations does not throw light on the psychological principles governing their development and does not explain the specific properties of their contents. With regard to these principles Samarin writes: "The principles governing the formation of associations and their actualization are given in the theory of I. P. Pavlov" *(ibid.*, p. 383), i.e., in the physiology of higher nervous activities.

It has already been noted that unlike Pavlov, Samarin views associations not as a temporary connection or a conditioned reflex but only as their psychological equivalent, i.e., he separates the psychological aspect from the physiological one. He then gives a purely descriptive characterization of these "purely" psychic phenomena. Finally, in turning to the principles governing the psychic phenomena he turns to physiology. This is precisely the approach that was usually followed by classical associationism.

Thus, even though he expresses his opposition to the substitution of psychology by physiology Samarin in fact follows the same path. In his theory psychology does not possess any specifically psychological laws; its specific properties relate to the level of phenomena (associations) which at best may be merely described in the psychological language but not explained in terms of psychological laws. Even though unlike Bogoyavlensky and Menchinskaya, Samarin does not equate explicitly the stages of assimilation with physiological stages in the development of analytical and synthetic activities of the brain he nevertheless does turn to physiology in his search for laws regulating the process of assimilation.

The second element that is common to these two variants of associationist-conditioned reflexes theory refers to the following: in both cases the stages of assimilation are identified in terms of their final outcome and the results of cognitive activities even though the nature of cognitive activity itself remains unanalyzed. Let us consider the stages of assimilation identified by Samarin. The *first stage* like those that follow is established not in a genetic manner and not through an analysis of students' activities that lead to these associations but exclusively on the basis of logic. With the help of an experiment resulting in the recording of data the author establishes the presence of various types of associations among students and then lists them in a specific order. The elements of such a series are then called stages in the process of assimilation.

He describes the first necessary stage as the *stage of local associations*. This represents the first step in acquiring knowledge and skills. These are isolated systemless knowledge. "Local associations represent the most inert link in man's knowledge" (*Ibid.*, p. 229). Taken by themselves local associations do not provide for the possibility of an act of thinking. They are employed in thinking activities in an accidental and non-goal-oriented manner. "A qualitative restructuring of established associations is needed" (*ibid.*, p. 235) in order that they may become an element of mental activity.

We thus see that as in the theory of assimilation of Menchinskaya and Bogoyavlensky the process of assimilation of knowledge follows a false course at the first stage. The associations that are developed at that stage call for a further qualitative restructuring. Since Samarin shows the necessity of this stage it follows that the process of assimilation cannot immediately follow a correct course and must inevitably be followed by a renewed learning. No evidence is presented, however, in support of such a view.

At the *second stage local systemic associations* are formed. While they represent systems of associations these are limited by "a textbook paragraph or chapter and particular knowledge concerning an individual object or phenomenon" (*Ibid.*, p. 259). In Samarin's view these associations already play a substantial role in the act of thinking: they serve as a basis for the selection of new facts and for comparing associations belonging to the given system. In his view that stage is also absolutely essential to the development of mental activities in man.

The *third stage* refers to the *formation of intrasystemic or intradisciplinary associations.* Intrasystemic associations make it possible for man to "reflect the objective reality with the help of a particular system of scientific knowledge or knowledge given by teachers as well as in a system of professional experience accumulated through a specific type of activity" (*Ibid.*, p. 296). In his view this type of association serves as a basis for a required adaptability of knowledge, abilities and acquired skills in corresponding disciplines. The formation of intradisciplinary associations calls for a systematic approach to acquiring the corresponding knowledge. In this connection Samarin lists a number of relations that he proposes as a basis for systematization: spatial relations, temporal relations, relations of ordering, quantitative relations, and causal relations.

A *fourth stage* is characterized by the development of *intersystemic or interdisciplinary associations.* These relations now exceed the framework of individual disciplines and encompass different systems of knowledge, abilities and acquired skills and form a variety of generalizations in relation to these systems. Intersystemic associations generalize the experience of numerous types of activities, "they lead to the development of the methods of mental and physical labour" (*Ibid.*, p. 343). Samarin writes that this type of association represents the highest level of mental activity.

Essentially this is all that is said about the process of assimilation. Even if one should agree with such a classification of associations the corresponding sequence may be accepted only as a programme of what should be assimilated (188). The stages of assimilation proposed by Samarin reflect only that order in which the assimilation of knowledge usually proceeds. Indeed, at first the child acquires individual disconnected information about objects and then he links them in some way to the object to which they relate; subsequently this knowledge is enlarged and encompasses a system of objects drawn from a given area of reality (in the course of learning various disciplines in school). Finally, some of the students learn to establish relations among individual disciplines as well. Let us assume that precisely such a sequence in accumulating knowledge is appropriate. But then we immediately face the problem of establishing the manner in which the *process* of assimilation of each of these types of associations should be organized. The theory of learning does not provide the corresponding answer.

Samarin refers to the findings of experiments that show that higher types of associations develop only among some of the students. In order to understand why this occurs it is necessary to identify the psychological mechanism relating to the cognitive activity of students that leads to these associations as its outcome. While Samarin assumes, of course, that the students must carry out some kind of specific activity in order to develop the corresponding associations this remains unanalyzed, and even the concrete structure and contents of such activities are not considered although their significance is recognized.

Accordingly, that conception cannot be viewed as a theory of assimilation since within it the process of assimilation is not analyzed. The author merely notes certain possible outcomes of the process of assimilation, but even these lead to objections. First, there is no evidence that the above-mentioned associations are always developed in the process of learning and in the indicated sequence. Second, the criteria that are employed in identifying them are not specifically psychological. In the classification proposed by Samarin associations that differ substantially from a psychological point of view must be viewed as belonging to the same type. For example, intradisciplinary associations may include both systems of generalized concepts and specific representations of memory since within a particular discipline knowledge may be assimilated in each of these forms. Thus, Samarin does not even view associations in terms of a specifically psychological description.[1] And he may be accused of the same shortcomings that he finds in the old associationists: namely, a neglect of the qualitatively specific properties that attach to transitions from cognition to representations and from representations to concepts.

Accordingly, the variant of the associationist-conditioned reflexes theory of learning proposed by Samarin cannot be accepted as a psychological basis for programmed instruction either. As was indicated in that conception the process of assimilation itself is not analyzed and its internal logic is not identified. It follows that that conception does not propose any specific model of process of assimilation, without which it is impossible to design a programme of controlling that process.

In order to convince oneself of the inapplicability of that theory for programming the learning process let us consider the principles of programming proposed by Samarin himself on the basis of his own theory. In one of his studies Samarin proposes the following system of requirements of the design of programmed materials:

1) the preparation of increasingly complex systematic assignments. In this connection subsequent assignments must require an actualization of knowledge that was assimilated earlier. In addition, that system of exercises must provide for a transition from direct and visual expressions of the contents being assimilated to increasingly abstract expressions;

2) the exercises must be varied;

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[1] A psychological classification of associations is presented in the book by P. A. Shevarev (185).

3) it is necessary to gradually shift from assignments calling for a standard method of actions to assignments requiring that a greater number of attributes be considered (153).

In another later study Samarin lists the following additional requirements (154):

1) a systematization of the knowledge that is presented;
2) a linkage with related courses;
3) provision for the development of abilities and acquired skills;
4) an application of the principle of individualization.

Once stated in such a general form most of these requirements do not raise any doubts. Indeed, they should be taken into consideration. But, first, it is not clear how this may be done concretely. Each of the stated requirements may be implemented in substantially different ways. Second, the overwhelming majority of these requirements relate to the content of the subject being studied. And only two of them relate to the activities of students. Even they, however, indicate only in a general way the objectives that must be achieved without specifying the ways in which this may be done. Indeed, the indication that it is necessary to develop abilities and acquired skills does not tell us anything about how one should proceed in order to actually achieve that objective. Finally, this system of requirements does not reflect, on the one hand, the particular stages of assimilation that Samarin views as indispensable. At the same time, most of these requirements are not related in any way to his "associationist-conditioned reflexes" theory. They are so distant from concreteness and psychological specificity that they may be associated with any theory of learning.

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This analysis makes it possible to conclude that the associationist-conditioned reflexes conception of learning expresses not a conditioned reflexes interpretation of the psyche but rather an associationist conception. While generally recognizing approaches to the psyche as a specific type of activity the authors who have developed that conception do not apply it in a concrete analysis of psychological facts.

In practice that theory of learning cannot be employed in programming the process of assimilation since it does not contain any indications concerning the procedure that must be followed in developing relevant students' activities.

No system of constructive principles follows from that conception that would permit a programming of the process of assimilation, a regulation of its course and to maintain assimilation on the right path from the very first.

Instead, it merely indicates that it is unavoidable to initially obtain defective knowledge that is subsequently to be qualitatively restructured. But should someone in fact attempt to construct a learning programme providing for a consistent generation of all indicated types of defects in learning it would still be necessary to search for a theory of the process of assimilation that would be appropriate to such an objective and that would provide information concerning the procedure that would be needed in order to develop the activities of students in such a way that the corresponding defects be unavoidably produced. There are no such programmes at present. And yet one finds in literature on programmed instruction in this country many suggestions that this theory be applied (9; 59).

In fact the authors of a number of studies indicate that they have already been successful in applying that theory. This is true, for example, of the study of I. A. Romanova (137). While the author cites associationist-conditioned reflexes theory as the basis of her study she does not then show how the teaching programme was designed on the basis of that theory and does not provide any evidence that that theory was in fact embodied in the corresponding programme.

In the case of programmed instruction in other countries the behaviourist theory of learning is widely cited and also serves as an operational psychological basis for designing teaching programmes.

Chapter Six

BEHAVIOURISM AS A PSYCHOLOGICAL BASIS FOR PROGRAMMED LEARNING

§ 1. The Essence of Behaviourism

Behaviourism appeared at the beginning of the twentieth century as a protest against subjective and idealistic forms of psychology which emphasized the study of consciousness through the method of introspection. Behaviourists supported the view that psychological methods should be objective and indicated that introspection is an inherently unscientific method since it does not admit any objective recording. But since behaviourists also believed that psychic phenomena could not be proved objectively by their very nature and would therefore never be the subject of genuinely scientific studies they proposed that psychic phenomena no longer be studied and that research be concerned exclusively with behaviour. Behaviourists emphasized that the main thing is what persons do and not what they think. Such a call for objectivity in psychology and an emphasis on the study of the behaviour of persons is unquestionably an important achievement and at the beginning of the twentieth century it represented a progressive development.

From the very first, however, behaviourism possessed two fundamental flaws. First, it did not overcome an epiphenomenalistic and idealistic interpretation of the psyche. Like the representatives of earlier empirical psychology behaviourists viewed the psyche as something closed within the subject that lends itself only to the method of introspection and that is not amenable to the objective methods of science. Instead of overcoming such an interpretation of the psyche they simply pushed it aside as an object for studies and continued to view it in terms of the subjective-idealistic approach.[1]

Second, behaviourists also interpreted the subject of their studies in a coarse mechanistic way: having separated behaviour from the psyche they reduced it to a system of movements. This led to a situation in which they referred to the behaviour of the stomach, of the intestines, and of man himself as similar phenomena. It is true, of course, that movement is part of behaviour but behaviour may not be reduced to a sum of movements. Moreover, behaviour frequently consists in not undertaking any movements. Accordingly, the presence of movements is not an attribute that is specific to behaviour. In this way, behaviourism represents a combination of a subjective-idealistic interpretation of the psyche with a mechanistic interpretation of behaviour. While earlier empirical psychology separated consciousness from behaviour and from the subject's activities behaviourism separated behaviour from consciousness and from the psyche as a whole (142).

Finally, behaviourists did not perceive the qualitatively specific properties in the behaviour of man by comparison with that of animals. They view man not as a social being but as a purely biological one. J. B. Watson, who was the founder of behaviourist psychology, indicates that it developed on the basis of studies of animals (323).

Behaviourism viewed the task of psychology as a study of relations between stimuli and responding movements of the organism (responses). It is this which underlies the famous formula of behaviourism: S-R.

It is the task of psychology to establish what combinations of stimuli (S) produce a specific response (R) that interests us, and conversely, what stimuli explain specific responses. The highest task of psychology is viewed as showing the manner in which human behaviour embodies individual responses and how one may learn to obtain the specified forms of behaviour by regulating a system of stimuli. Thus, behaviourists are interested only in those elements that influence the person and in his response to such influences. The key processes which mediate the linkage between a stimulus and a response are not considered and are veiwed as subjects of physiology. Yet, it is well known that for all that is living the actual effect of external influences depends on the nature of the internal state of the organism that is being subjected to stimuli. In this regard human behaviour provides no exception. The stimuli that a person experiences are always refracted through a system of existing needs and tasks that he confronts and are mediated by the nature of the activities (including psychic activities) that are directed at these stimuli. It is therefore not possible to envisage a one-to-one relation between stimuli and the responses. Since the 1930s the interest in behaviourism began to decline. By that time behaviourism had lost its initially simple formulation. In experimental studies of behaviour internal conditions and the psychic factors continued to express themselves and behaviourists began to recognize this. But since they had not overcome their idealistic interpretation of the psyche they moved in the direction of a linkage with earlier empirical psychology.

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[1] As S. L. Rubinstein correctly observes behaviourism represents the reverse side of the introspective idealistic psychology of consciousness: an unconscious activity of blind responses was juxtaposed to inactive consciousness. Both approaches are expressions of a separation between man's activities and his consciousness (145).

In particular, behaviourism was greatly influenced by Gestalt psychology.[1]

It is widely known that the "demise" of behaviourism was reflected vividly in the works of E. Tolman (320). The entire basic system of concepts of introspective psychology was in fact reintroduced in his neo-behaviourism, but an attempt was made to interpret them in a behaviourist way and to express them through objective data concerning behaviour. While J. Watson reduces behaviour to a system of movements Tolman holds the view that behaviour is qualitatively specific as a psychological phenomenon and may not be reduced to the sum of elementary responses in terms of which it is observed. Under the clear influence of Gestalt psychology he also emphasizes the integrated character of behaviour. Its principal characteristic in his view is its goal-oriented nature. This is viewed as the primary element. All psychic processes are then viewed as secondary in relation to behaviour. In particular, motivational processes, cognitive processes, abilities, etc., are viewed as intermediate links ("determinants" of behaviour) mediating responses. According to Tolman, the final response is, first, determined by the stimulus and the initial physiological state of the organism which operate as primary causes and, second, by mediating determinants (intermediate variables),[1] which operate between initial causes and final behaviour.

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[1] For an analysis of the philosophical foundations and various schools of behaviourism see the studies of S. L. Rubinstein (145), A. N. Leontiev (86), O. K. Tikhomirov (177), and M. G. Yaroshevsky (195).

In this way behaviourism has come to recognize that it is not possible to study behaviour in terms of the stimulus-response formula. The study of behaviour unavoidably leads to a consideration of psychological factors and a consideration of the role of consciousness. Tolman correctly notes in this connection that consciousness must be defined objectively on the basis of data on behaviour. But instead of recognizing the integral unity of behaviour and consciousness and attributing to consciousness a real vital function he seeks to reduce consciousness to behaviour and to deprive it of its specific properties. As in the case of introspective psychology he transforms consciousness into an epiphenomenon that is separated from the subject's real interrelations with the world. Such an assertion introduces insoluble contradictions into Tolman's system by making it impossible to define consciousness in a functional manner on the basis of objective properties of behaviour. For if consciousness does not introduce any qualitative properties into behaviour it is not possible to establish where it is active in behaviour and where it is not. Rubinstein concludes his analysis of Tolman's system with the following observation: "Behind behaviourism's psychological pseudo-objectivism one does find a clear epistemological subjectivism" (145, p. 306).

During the more than fifty years of its existence behaviourism has experienced substantial changes largely in the direction of its recognition of the role of the psyche interpreted in the spirit of earlier subjective-idealistic psychology. This has led to an abandonment of its initial positions and to its transformation into an eclectic demistream that today exists in the form of several distinct schools.

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[1] In analyzing Tolman's interpretation of variables Gérard de Montpellier writes that "despite Tolman's assertion [321, p. 102] that introspection does not play a role in determining that variable, it still appears to be difficult to deny the fact that the specific nature and active role of such a process will ultimately depend on introspective analysis". This, he adds, indicates that "one should not view that conception as being consistently behaviouristic" (273, p. IV-197).

§ 2. Behaviourism and the Theory of Learning

1. The Basic Principles of Learning

The principles of a behaviourist theory of training were formulated by E. Thorndike who devoted much time to studies of the training of animals. His experiments with animals have served, on the one hand, as a basis for the emergence of a behaviourist approach in psychology. At the same time he made use of them in elaborating the foundations of educational psychology.

The justification of transferring principles of animal learning to human learning is not doubted by Thorndike since in his view there are no qualitative differences between these two processes. In this connection he writes that the development of the animal world is a quantitative growth and a quantitative complexification of the same process of connections between situations and responses that one finds among all vertebrates and even lower animals (318).

It is Thorndike's view that man differs from animals merely in the abundance of the associations that he develops between external situations and the corresponding motor reactions as well as in the rate with which these associations are formed and the complexity of their intermingling. He writes: "His [the human] intellect we have seen to be a simple though extended variation from the general animal sort" (*Ibid.*, p. 182). Thus, the behaviourist approach to education is based on a biological view of that process and a failure to consider the qualitatively specific properties that distinguish it from the training of animals. It is true that one can find many observations in Thorndike's work to the effect that in the course of development there occurs not merely a quantitative growth in associations but also a qualitative growth and that the corresponding process attains its greatest level of development in the case of man. He also points to the importance of speech in man's psychic development (317, pp. 168, 186, 188 et seq.). But these are only passing observations that are not employed in the analysis of the process of human education. Thorndike's actual point of view is that "the general pattern and features of the learning are extraordinarily alike over almost the entire range" (318, p. 163).

According to Thorndike the process of learning is the process of establishing specific connections between a given situation and a given response and also the consolidation of these connections.

He regards the law of effect and the law of repetition (exercise) as well as the law of readiness as the principal laws bearing on the formation and consolidation of connections between stimuli and responses.

Thorndike places particular emphasis on the law of effect, which he defines as follows: "When a modifiable connection between a situation and a response is made and is accompanied or followed by a satisfying state of affairs, that connection's strength is increased; when made and accompanied or followed by an annoying state of affairs, its strength is decreased" (316, p. 4). He notes further: "By a satisfying state of affairs is meant roughly one which the animal does nothing to avoid, often doing such things as attain and preserve it. By an annoying state of affairs is meant roughly one which the animal avoids or changes" (317, p. 50). We thus see that effects may be both positive and negative; the positive effect of the connection that has been formed refers to the point that such a connection leads to experiencing a state of satisfaction and of achievement; the effect of satisfaction operates directly on the connection that has been formed and consolidates it. Conversely, the experiencing of a disappointment and of failures (negative effect) operates destructively on the connection that has been formed and brings about its disintegration. In this connection, Thorndike observes that positive effects operate more rapidly in forming a desired connection than do negative effects in destroying undesired connections.[1]

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[1] The law of effect has been elaborated further in the studies of C. L. Hull, who refers to effect as to the gradient of reinforcement. Unlike in the case of Thorndike he views reinforcement not as a satisfying state of affairs but as a reduction in need. Thus reinforcement presupposes the existence of needs associated with the given connection. It is Hull who systematized the theory of reinforcement and applied it to all forms of training (247; 248; 249).

The law of exercise refers to the view that the more frequent the repetition of the time sequence of a stimulus and the corresponding response the more secure will be the connection. In this connection, Thorndike emphasizes that by itself a repetition of the time sequence of a stimulus and of a response without a subsequent positive effect (reinforcement) does not lead to the development of a connection, i.e,. repetition is effective only when combined with reinforcement.

The law of readiness (or preparedness) refers to the dependence of the rate with which a connection is developed on the extent to which it corresponds to the subject's current state. "Every connection," Thorndike writes, "is made by a particular person or mind or brain in a particular status" (*Ibid.*, p. 120).

In addition to these three principles which are known as the "laws of learning" Thorndike lists a number of additional conditions that contribute to the development and reinforcement of connections between external influences and corresponding responses. They include an awareness of the association of certain stimuli with certain responses and the extent to which such connections are acceptable. The association of stimuli with responses refers, for example, to the fact that they are viewed as belonging to a common class of objects (for example, they are parts of speech) or else as elements of some larger entity.

Thorndike also indicates that the rapidity with which a connection is developed depends as well on the ease with which the stimulus is identified and the extent to which the corresponding response is available.

It should be noted that Thorndike opposes "the overzealous type of behaviorist who allows human nature no responses save the acts of muscles and glands" *Ibid.*, p. 102). He notes that the activity of neurons is not limited to the conveying of neural currents from external sensory organs to external motor organs. They also possess their internal life: they create internal connections among themselves and among images, ideas and feelings brought about by their behaviour, but while he recognizes the reality of the psyche Thorndike does not consider it in his analysis of education which he limits to the framework of stimulus-response-reinforcement. The relevance of the psyche to the formation of connections is not shown and is not considered. The psyche remains an internal process that proceeds in parallel to neural activities and is not linked to the subject's behaviour in any way; its function remains unknown. Such an interpretation of the psyche does not differ in any way from that of the earlier subjective-idealistic psychology.

The laws of learning listed by Thorndike constitute the foundations of all theories of learning in contemporary behaviourism; researchers representing its various branches relate their analysis of any training of animals or education of persons to the scheme "stimulus-response".

The differences between individual branches of behaviourism relate to the manner in which individual principles of training are understood as well as their role in the process in which connections between stimuli and responses are formed and reinforced. They also relate to the nature and role of certain additional conditions.

In particular, there exist three different points of view concerning the role that is attributed to the law of effect (the principle of reinforcement). Some representatives of the behaviourist approach to education (Thorndike, Hull, and others) consider that training is not possible without reinforcement and the positive effect that is experienced by the learner as a result of the required response.[1] That effect is described as a weakening of attraction, a consequence satisfying the organism, success, satisfaction, reward (305).

A second group of behaviourists (E. Tolman, E. R. Guthrie, and others) consider that reinforcement is by no means required for learning. Instead they emphasize the proximity of stimuli and responses.

A third group of psychologists (B. F. Skinner, G. Razran, and others) adhere to an intermediate point of view; they consider that two different types of training exist, namely, one that is based on the law of effect and another that is based on the law of proximity for which reinforcement is not required.

Skinner, who is the founder of programmed learning, is thus a representative of one of the schools of contemporary behaviourism. His conception of learning is also based on the principles indicated by E. Thorndike.

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[1] Unlike Hull, Thorndike believed that it was possible to learn without relying on the law of effect even though in general he attributed to the latter a decisive importance.

2. Specific Characteristics of B. F. Skinner's Theory of Learning

As a positivist Skinner generally opposes all theories of learning and proposes to develop the teaching process on the basis of experience. He asserts that theories usually lead to a waste of time and to confusion. When facts are fully in order, he writes, theories have a tendency to vanish. It is Skinner's view that psychological research must be carried out in terms of a functional description of directly observable facts (299).

Nevertheless, an analysis of the principles that he proposes for programming the process of learning shows that they are based on behaviourist theory. As in the case of other behaviourists one finds in Skinner's view of human learning an orientation on biology. It is as a result of experiments in training animals that he has formulated all his basic principles of education: initially Skinner worked with rats (1938), and later with pigeons (1948). His basic method in working with animals was to gradually guide them towards a specified response.[1]

This is one of the experiments with pigeons. First the weight of the pigeon is reduced to 80 per cent of its initial value and after that it is fed once every 24 hours. The pigeon is placed in a cage into which a dish with food is entered automatically. The pigeon quickly learns to approach the food following a sound that precedes the insertion of the dish.

Following such a preliminary training the pigeon is not fed during a period of 24 hours preceding the experiment. The objective of the principal experiment is, in the present case, to teach the pigeon to peck at a black spot drawn on a white card. As soon as the pigeon accidentally looks in the direction of the card it is given food (to reinforce the corresponding response). If he then takes even one step in the direction of the card he receives the next reinforcement. Gradually the pigeon approaches the card. After that the experimenter waits until it accidentally pecks the card and again gives him a reinforcement. In this way the pigeon is gradually guided to perform the desired response, namely to peck at the black spot. Skinner calls such responses *operant* or emitted responses. They are different in his view from the classical Pavlovian reflexes which he calls *respondent* or elicited (294).

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[1] Earlier that method was successfully applied by V. Durov in training circus animals (37).

In Skinner's view the distinction between the two relates to the following. First, respondents (classical reflexes) are always produced by known stimuli. In the case of operant behaviour the stimulus to which the organism responds remains unknown. In such a case the experimenter does not produce a stimulus causing a response but observes the behaviour of the organism and when the reaction interesting him emerges accidentally he reinforces it. Operants may be linked with the preceding stimulus (usually this is what does occur), but in Skinner's view that stimulus serves merely as an occasion for an operant behaviour and not as a cause for the response.

Second, in developing respondent behaviour reinforcement is associated with the stimulus (Skinner calls such responses behaviour of Type S). A conditioned stimulus is given simultaneously with the unconditioned; a connection between the conditioned stimulus and the response emerges as a result of the principle of contiguity, namely, as a result of the temporal contiguity of the conditioned stimulus and the response. In such cases the unconditioned stimulus is given independently of whether the organism responds to the conditioned stimulus or not. It is employed in order to activate the desired response which is subsequently associated with the conditioned stimulus.

In the case of operant conditioned reflexes reinforcement is not given until the organism performs the conditioned response. In other words, in such cases it is not the stimulus which is reinforced but the response (Skinner calls such responses behaviour of Type R). The basic law that governs this kind of development of behaviour is the law of effect: it is success, the consequences of responses satisfying the need that determine the learning. In such cases reinforcement depends on the response and the response itself produces the reinforcing stimulus. In some cases reinforcement appears as a direct consequence of the conditioned response that is carried out (a rat presses a lever and as a result a particle of food appears that it eats); in others it is mediated by the activities of the experimenter (a pigeon pecks at a black spot and the experimenter gives him the dish with food).

Finally, in the case of respondent behaviour (classical reflexes) conditioned responses represent a recreation of a response to an unconditioned stimulus (the animal salivates following the appearance of a light signal, although initially salivation was a response to food, namely, to an unconditioned stimulus). In the case of operant behaviour conditioned responses do not resemble responses that follow the reinforcing (unconditioned) stimulus. Thus, for example, the pressing of a lever, or pecking (conditioned responses) are unlike chewing and salivating (responses to a reinforcing stimulus).

Skinner distinguishes sharply between these two types of reflexes. He has even attempted to differentiate them in terms of topographic attributes: operants, in his view, are associated with skeletal muscles and are controlled by the central nervous system; while respondents are associated with smooth muscles and with glands and are controlled by the autonomous nervous system. One cannot agree with such a juxtaposition. A closer analysis indicates that both types of responses repose on the same principles of activities of the nervous system based on reflexes. An organism's response is always a response to a specific influence. Conditioned responses always arise only in those cases in which the corresponding stimulus is objectively associated with another (conditioned or unconditioned), which is of vital importance for the animal or for the person in question. Skinner is mistaken when he asserts that operant responses may appear without any influence on the organism. Let us return to the behaviour of the pigeon. Initially, it is true that a turning of the head or a pecking at the spot does not have any relation to food; they may be produced by unconditioned orienting reflexes. In that case, accordingly, they are not yet conditioned reflexes. Once the experimenter reinforces them with food, however, they become conditioned reflexes. In this case it is the spot that operates as a conditioned stimulus and the pecking which represents the conditioned response. Without a need for food and without the presence of objective connections established in the course of the experiment between the appearance of the spot and that of food the response of pecking would of course not be developed. We find the same principles as in the development of a conditioned salivating reflex in response to a light or sound stimulus. The difference lies only in the nature of the conditioned response and in the method by which it is called forth. As for the nature of the conditioned response it is known that Pavlov selected salivation merely because of convenience in carrying out experiments. But in the experiments of Pavlov, too, one finds conditioned motor responses: after the appearance of a conditioned light or sound stimulus the animal immediately turned its head towards the feeder. One also finds in the works of Pavlov descriptions indicating that some of the experimental animals licked the bulb that served as a conditioned stimulus (118). There is no essential difference between that response and the pecking at a coloured spot by a pigeon. Finally, Pavlov's school also used the animal's movements as a conditioned stimulus. For example, a passive bending of a dog's paw served as a conditioned food stimulus: the experimenter bent the dog's paw and then gave food reinforcement. As a result the bending of a paw became a conditioned signal for food.

Skinner's distinction between respondent and operant reflexes on an anatomical basis is not at all persuasive: as we have seen motor responses may be obtained by both respondent methods and operant methods. The absence of a justification for distinguishing between these two types of reflexes has been considered both in Soviet literature (e.g., [5]) and in American publications (e.g., the book of E. J. Green, [237], Chapter Three).

In the education of persons Skinner ascribes a decisive importance to operant behaviour since, in his view, man's behaviour is primarily of an operant character. He associates acts of operant behaviour with controlled behaviour and respondent acts with involuntary behaviour.

B. F. Skinner lists several types of operant behaviour:

1) instrumental conditioning: the responses being developed lead themselves to a reinforcement and serve as a means or instrument for achieving this. An example of this may be the behaviour of a rat in an experimental situation; as a rat presses a lever this causes the food to appear;

2) teaching with the help of trial and error. For example, an animal may choose a correct move within a labyrinth leading to either food or freedom;

3) verbal conditioning (the development of various types of verbal behaviour);

4) the development of concepts and the sudden solution of problems.

As a measure of the intensity of operant responses Skinner relies on the rate of the response. Increases in response rate serve as an indicator of an increased probability of response.

Skinner seeks to maintain a positivist position and to limit himself to descriptions as a matter of principle. As a result he avoids statements concerning any mediating links that are not observable in experiments. He prefers to study functional relations among directly observable elements, such as external behaviour and the particular external influences on the organism that lead to a change in behaviour.

Originally, Skinner viewed reflexes as the unit of analysis of behaviour (294). He used that term to describe a connection between a specific stimulus and the corresponding response. Later he noted in a number of studies that it is fully justified to analyze behaviour at the level of operant responses. His characterization of conditioned operant responses includes the stimulus which, in his opinion, is the source of the response, as well as the response itself and the reinforcement. Thus, the analysis of behaviour follows the same general behaviourist scheme: stimulus-response-reinforcement.

Similarly, Skinner fully accepts the behaviourist laws of learning. He attaches primary importance to the law of effect (the principle of reinforcement, according to Watson). Empirically that principle is expressed in the fact that responses leading to success ("rewards") are reinforced and retained while responses leading to failure ("nonreward") become weaker and disappear.

It should be noted that among those supporting the law of effect there are a number of views on the nature of reinforcing factors and the ways in which they operate on the resulting connection (see, for example, Gérard de Montpellier [273]). Behaviourists define reinforcers depending on their effects: any stimulus is a reinforcer if it increases the probability of a response. The stimuli that happen to act as reinforcers are divided into positive and negative. A *positive* reinforcer is a stimulus which, when applied following an operant response, strengthens the probability of that response. A *negative* reinforcer is a stimulus which, when removed following an operant response, strengthens the probability of that response. (For example, a rat placed in an electrified cage may interrupt the electrical current by pressing a lever and thus exclude an undesired stimulus. This leads to a situation in which the number of times that the lever is pressed is increased, i.e., the operant response is intensified. In this case electrical current is the negative reinforcing stimulus.) Skinner notes that negative reinforcement should be distinguished from *punishment*. In the case of punishment there is not an exclusion but an inclusion into the experimental situation of an "unpleasant" stimulus. (For example, the animal carries out the operant response of pressing a lever. If after it has pressed a lever the animal is given an electrical shock this will represent a punishment since in the given case the electrical shock contributes not to an intensification of the response but, on the contrary, to its attenuation.)

Reinforcing stimuli are also divided into primary, secondary, and generalized. The primary reinforcing stimuli are characterized by the fact that they produce a reinforcing action without any preliminary training (an unconditioned reinforcement in the terms of I. P. Pavlov). Secondary reinforcing stimuli are those which initially do not have any reinforcing effect but as a result of an association with reinforcers acquire such an effect (a conditioned reinforcement in terms of I. P. Pavlov). If a neutral stimulus is associated with many reinforcers, it becomes a reinforcing stimulus in all those situations in which the latter operated; a secondary reinforcer of this type is called generalized.

On the basis of experiments with animals Skinner distinguished several reinforcement regimes. The development of operant responses may occur following reinforcement of each response. Under such a regime the response develops most rapidly, but it proves to be quite unstable: as soon as the reinforcement ceases to operate a rapid decline in the response occurs. In addition to that regime four others are specified, two regular regimes and two irregular ones. Under regular regimes reinforcement is given either as a reward for the organism's execution of a specified number of responses (partial reinforcement), or else after a specific period of time (interval-oriented reinforcement). In the case of irregular regimes reinforcement is not associated with a specific number of responses nor with a specific interval of time. Experiments have shown that those irregular regimes are most effective under which the reinforcer is activated after a varying number of responses carried out by the organism (229).

While Skinner also recognizes the importance of the law of exercise he emphasizes that that particular law operates only because in the real process of learning it is not possible to isolate the response being developed. If this were possible the response would develop following a single reinforcement (297). (That point of view is very close to the position of E. Guthrie [238], who also believes that the development of a connection between a stimulus and a response is possible following a single trial. Skinner, however, believes that reinforcement is necessary and for him it is this which constitutes a single event; Guthrie, on the other hand, believes that a single combination at the moment of time of a stimulus and a response is sufficient to develop a response.)

The so-called law of preparedness constitutes an organic part of Skinner's system. Reinforcement may be effective only in those cases in which it corresponds to the organism's current state. Skinner prepares animals for experiments in the same way as did Pavlov: in experiments involving reinforcement through feeding animals are initially fed insufficiently.

Aside from these basic principles of learning Skinner introduces additional ones: the principle of discriminating stimuli and the principle of differentiating responses. Discrimination of stimuli refers to the point that operant responses are carried out only in situations in which specific stimuli are introduced into experimental situations and that such responses do not take place in the absence of such stimuli. (For example, a rat presses a lever only following three light signals). The differentiation of responses refers to the point that given a specific stimulus the animal produces an operant response whose form and intensity are rigorously defined. For example, it is possible to teach a rat to press a lever with a specified intensity or else to hold the lever over a specific period of time. An ability to discriminate stimuli and to differentiate responses is attained by a specific regime of reinforcement: in the development of an ability to discriminate, it is attained only in those cases in which the animal responds to specific stimuli (or else to their properties); in the case of the differentiation of responses, it occurs only in situations in which the animal produces a response of a specified type (294).

As we see, Skinner's theory of learning is a typical behaviourist theory and it does not differ in any respect from that of Thorndike with regard to fundamentals. In analyzing Skinner's approach to learning E. R. Hilgard wrote: "Skinner's operant conditioning is a development more along the lines of Thorndike's learning by selecting and connecting under the law of effect" (239, p. 82).

Skinner carries over the finding of studies of operant behaviour of animals to persons (295) since he does not see any qualitatively specific properties in human learning. As does Thorndike Skinner views a shift from animals to humans merely as a quantitative complexification in behaviour. In one of his studies he writes: "Comparable results have been obtained with pigeons, rats, dogs, monkeys, human children, and most recently... with human psychotic subjects. In spite of great phylogenetic difference, all these organisms show amazingly similar properties of the learning process" (301). Skinner states explicitly that the greater part of knowledge on the process of learning is obtained by studying the behaviour of lower organisms. But these results, he continues, are applicable to the human organism as well. In his book *Science and Human Behavior* (295) all major data relate primarily to experiments with rats and pigeons. And although later he has carried out experiments on human subjects, Hilgard rightly observes that he extends his theory to the sphere of human learning in terms of analogies rather than on an experimental basis (239).

In Skinner's view the only element that distinguishes human behaviour from that of animals is speech. But since, in his view, verbal behaviour is governed by the same principles as other acts of operant behaviour it must be analyzed and developed in accordance with the same framework (296).

Skinner analyzes the process of human learning in terms of the concepts of behaviour as well. He defines the objective of education as the acquisition of a preprogrammed system of external responses or, in Skinner's terminology, of a behaviour set.

Since he considers human learning to differ from that of animals only in that it may occur at a verbal level a system of verbal (speech) responses must be defined in specifying the objectives of human education: correct answers to questions, recitation of texts, the solution of problems, etc. In this connection he calls for a precise specification of the system of responses that we wish to obtain from the student at the end of the education process. Thus, for example, in learning the French language the student must: 1) repeat phrases with a good pronunciation; 2) read texts in accordance with rules; 3) write a dictation in

French; 4) find required words in a dictionary; 5) to find subjects and other parts of sentences; 6) to state instructions in the French language, etc. (300).

These complex acts of behaviour may be subdivided into elementary acts and individual operant responses. But no matter how one divides them, in Skinner's system the goal of education must be represented as a set of *external* acts of behaviour. The nature of internal psychic activities leading to that behaviour is not taken into account. The correctness of the specified external responses is the only indicator that is necessary to establish a state of knowledge acquisition. This typically behaviouristic indicator of learning is employed by Skinner as a basis for developing principles for programming the learning process.

§ 3. Skinner's Principles for Programming the Process of Learning

Skinner bases his analysis on the correct proposition that behaviour may be learned only by correctly performing the corresponding behaviour; action may be assimilated only through acting. One cannot object to this: this is the general form of the principle of active teaching that everyone accepts. But as a true behaviourist and positivist Skinner considers that it is possible to take into account in action and in behaviour only those elements that are directly observable and as a result action is reduced in his work to external motor responses while behaviour is reduced to their sum.

As a result of this the criterion of active performance in the process of instruction is reduced to external responses. As T. V. Gabai correctly observes, B. F. Skinner "rejects as a matter of principle the greater hidden part of the 'iceberg' representing teaching activity and considers only the visible part, namely, the externally expressed final link of that activity" (31, p. 18).

External responses are merely an element of behaviour. Moreover, they may, in fact, relate to fundamentally different types of behaviour. Accordingly, the guidance of external responses does not represent a regulation of actions while the development of a set of external responses does not represent the development of behaviour. That, however, is our own point of view. As for Skinner's position, it logically requires that emphasis be placed on external responses. This is why all the principles of programmed learning proposed by Skinner relate to the solution of two problems, namely, achieving a desired external response and its reinforcement. In order to achieve this he relies on the same method of guiding with the help of which he has been successful in training pigeons and rats (301). The principles for programmed learning that are employed by Skinner represent a transfer of findings obtained in experiments with animals.

The only specification mentioned by Skinner that reflects the specific properties of teaching human beings is an emphasis on the importance of logical rigour and consistency in the presentation of learning materials.

All other principles that he proposes follow directly from the behaviourist laws of learning established in experiments with animals.

The complex behaviour that is to be obtained at the end of the learning process cannot develop in a final form immediately and must therefore be developed in steps, by individual elements. In this connection Skinner emphasizes that each step must be sufficiently simple so that students may perform it without errors. He particularly emphasizes that learning must proceed without errors. He attributes this to the fact that in learning we always seek to develop particular acts of behaviour and they must be correct from the first. The performance of incorrect responses may lead to a weakening of correct ones or even to a reinforcement of erroneous responses instead of the desired ones. This is why he considers that learning must be easy and must make it possible for students from the first to carry out desired responses.

The desired size of a step is found empirically. It is on the basis of experience that a sequence of steps is defined and then verified. If in carrying out these steps students perform more than five per cent errors it is considered that the learning programme is difficult. It is then simplified and again verified. In this way the desired programme is gradually found.

As a result each subject being studied is divided into thousands of small segments (frames, fragments). (A course in plane geometry, for example, programmed by E. B.

Curtis in accordance with Skinner's system contains more than 11,000 frames [221].)

The subdivision of the learning process into small steps is the first programming principle defined by Skinner. It is intended to make possible from the very first a correct execution of programmed responses. That is also the objective of a second principle, namely, the presence of a system of prompting within the learning programme.

Initially the desired response is given to the students in a prepared form (the maximal prompting level), then individual elements are omitted (a gradual attenuation of prompting), and towards the end a completely autonomous execution of responses is expected (the removal of prompting). For example, in the assimilation of a concept the corresponding definition is initially given in a full form, then with an omission of a single most easily recalled word, then with omissions of other words which are more difficult to recall. After a number of such frames students must reproduce the corresponding definition fully without assistance. Similarly, in the memorization of a poem a four-lined poem is initially given fully, then with an omission of a single word, then two words and then an entire line. After several frames the student is shown four broken lines instead of the initial poem. He is then expected to reproduce the entire poem without assistance.

The attention of persons designing programmes is directed entirely at providing for a correct filling of omitted words. As for what takes place in the minds of students and whether they understand the contents of the segment in which they enter omitted words, this remains unknown. In particular, the fact that a student may correctly enter omitted words in the definition of a concept may merely indicate that he has memorized the definition. But a knowledge of a definition, as is well known, does not at all indicate that the concept has been assimilated. That knowledge may be purely formal without any understanding of the system of essential attributes that underlie it and without any ability to apply it.

As for the second task, namely, the reinforcement of responses this is achieved in programmes of the Skinner type primarily through an immediate reinforcement of each correct step (applying the law of effect). It is Skinner's view that an insufficient number of acts of reinforcement or else their inadequateness or poor timing represent one of the major defects of existing teaching practice. Distant objectives of education mentioned to students cannot serve as active reinforcements. It is necessary to develop a system of reinforcements that can be directly included into the behaviour of students and stimulate desired forms of behaviour. Skinner notes that human behaviour changes under the influence of even small achievements: a greater understanding after certain doubts, or simply the possibility of moving further after having mastered one of the operations of an action. All this operates as a positive stimulus in the learning process.

At the same time Skinner notes that correct types of reinforcements are not always easily found (301; 300). Programmes constructed on the basis of the principles defined by Skinner employ verbal forms of encouragement as reinforcements, and displays of examples that make it possible to confirm the correctness of one's own answer. Small and easy doses of material make it possible for students to frequently confirm to themselves that their answers are correct and to frequently experience their successes. Skinner believes that this not only forces correct answers but also creates one's readiness to proceed further. In this way the requirements of the law of readiness are carried out.

In order to achieve reinforcement elements that are omitted in individual frames of a programme (in the course of learning with the help of programmed textbooks) are either placed below individual frames or else beside them or on the following page. Following their formulation of omitted sections (the construction of answers) students are expected to compare their answers with the one presented in the programme. In executing programmes with the help of teaching machines the machine displays the answer immediately after the corresponding response is carried out by the student.

Frequent repetitions are also employed in order to reinforce responses (the requirement of the law of repetition). For example, in a course of plane geometry programmed by E. Curtis (221) frames carrying definitions of concepts and proofs of theorems are repeated tens of times. Even the rule for denoting angles is repeated more than twenty times during the first 500 steps.

Thus, the Skinner approach to programming is based on a typically behaviourist conception of learning. Programmes that are constructed on the basis of the corresponding principles represent a long sequence of small frames containing specific information on the subject being studied. Each frame contains omissions, either several letters or a word or several words. The problem is only to fill in the omissions either independently or with the help of promptings. The requirement that all responses be written ("constructed") also follows logically from the behaviourist view of the learning process. In this connection N. A. Crowder writes: "The student response is ordinarily a 'constructed' response, as it was early believed by the linear theorists that 'thinking' a response could not properly be called 'behaviour' " (220, p. 251). After writing the omitted elements the student is required to verify his answer following a display of the answer contained within the programme.

Whether a student carries out a problem correctly or not he is expected to move to the next frame. Thus, a correction of the programme is not envisaged. This is because programmes anticipate that students will proceed without errors. This is achieved, as Crowder correctly notes, by reducing the level of difficulty to that of the weakest student. "We can produce virtually error-free programs if we are careful never to assume knowledge that the most poorly prepared student does not have" (*Ibid.*, p. 253).

Thus, all students employing programmes designed according to Skinner's principles are given the same sequence of frames and they must all perform the same learning steps (this is why the programmes are called linear: all students follow an identical line). The individualization of learning refers only to the rate of progress. As for the level of difficulty it is the same for all students. It is true that at the present time some linear programmes are followed by different students at different levels of comprehensiveness: having successfully filled in a specific number of omitted elements students are permitted to "skip over" a certain number of frames. This provides a basis for a somewhat greater measure of individualization and for a certain measure of correction in the learning process.

The fundamental shortcoming of these programmes is that they ignore the cognitive activities of students. Under such programmes the cognitive activities remain unknown and are in fact not regulated.

Unlike the classical behaviourists, Skinner is not afraid of psychological terms. He even refers to the need to develop thinking and attentiveness. In this connection, he points out that in order to develop attentiveness, for example, it is not sufficient to direct it to external aspects of the material being studied. It is his view that most audio-visual devices do not teach attentiveness because they stimulate (reinforce) students before they begin to see or listen. In his view thinking and attentiveness are acts of operant behaviour. For example, with regard to the solution of problems, he writes that the corresponding process does not include any new factors different from those that operate in the development of operant behaviour and accordingly the teaching of thinking must follow the scheme of the development of operant behaviour: "expended" attention should be reinforced, as well as "completed" thinking (295; 297). As we see this refers at best to an amplification of already existing acts of cognitive activity.

If one considers the approach proposed by Skinner it becomes evident that in his learning programmes, he speaks of reinforcement only in acts of perception and memory. The analysis of programmes constructed both by Skinner himself (244) and by other authors, on the basis of the principles proposed by Skinner (221) shows that in order to fill in omissions in frames, these types of cognitive activity are sufficient, and thinking is not required. Accordingly, thinking activities of students are neither programmed nor controlled. Their development, when it does take place, occurs in an unorganized manner. Under such conditions the probability of acquiring rational forms of thinking activity is too low.

An analysis of programmes constructed on Skinner's principles thus shows that not only do they not guarantee the development of new types of rational thinking activities but they do not require an application of already developed activities of this type either. A programme may be completed successfully only with the support of perceptive and mnemonic activities. In this connection, Skinner's references to the need to teach thinking remain unrealized.

§ 4. Behaviourism as a General Basis for American Systems of Programmed Instruction

Behaviourism underlies not only Skinner's system of programming: it is the common basis of the American approach to programmed learning. Differences in individual approaches relate only to specific problems associated with the implementation of the same general scheme of stimulus-response-reinforcement, and of the same laws, that of effect, repetition and readiness. In this connection, it should be noted that approaches to work in programmed learning frequently differ not in terms of the model of learning on which the programming of the process of assimilation is based but in superficial nonessential attributes: branching or linear programmes; selected or constructed answer; etc. We fully share the point of view expressed by D. J. Klaus who represent the American approach to programmed instruction that theoretically it is more correct to distinguish types of programmed instruction not in terms of the attribute of linearity or the use of branching but in terms of the theoretical basis that they embody.

This is why we cannot agree with L. M. Stolurow, Ye. I. Mashbits and V. M. Bondarovskaya when they refer to differences in the approaches to programming the process of learning of S. L. Pressey, J. G. Holland, J. Beck, L. J. Briggs and others (308; 98). We do not find any grounds for this.

In particular, the differences between Pressey and Skinner are merely that Pressey feels it possible to teach through the method of trial and error, while Skinner emphasizes the need for an error-free process. In this connection Pressey relies on a selective approach to answers while Skinner recommends that a construction of answers be employed. They also differ in the importance that they attribute to logical rigour and consistency in the material being studied: Pressey does not consider this requirement to be essential, while Skinner emphasizes its importance. The basic principles on which they rely in analyzing and programming the learning process are identical (284).

Similarly the Ruleg system developed by J. L. Evans, L. E. Homme, and R. Glaser also represents a concrete and detailed elaboration of Skinner's principles and, above all, the principle, that calls for a rigorous logical order in presenting material and the principle of prompting (227). Nor are there any grounds for viewing the programming principles proposed by J. Holland, L. Briggs, J. Beck, and D. Porter as distinct approaches: they are instances not only of the behaviourist approach to programming but of the system proposed by Skinner.

In particular, Holland simply indicates additional means that make it possible to apply Skinner's principles to the process of learning. Indeed, the content of his first principle is merely the requirement that the material be presented in small doses. His second principle notes one of the ways to avoid erroneous answers. In this connection he proposes that each new word be used repeatedly in the programme before the student is asked to employ it as an element of an answer that is being constructed. The seventh principle as well is concerned with the avoidance of errors. It recommends that much care be given to the formulation of the material to be presented in individual frames. The third principle proposes that a rule be presented first and then an example, etc. (243).

Similarly the programming rules of J. Beck and D. Porter are concerned with the creation of certain additional conditions for obtaining correct responses from students (203; 283). The principles proposed by these authors simply represent a certain further development and in some cases simple detailed elaboration of propositions advanced by Skinner.

In the case of Crowder's branching programming (220) the underlying basis is still the behaviourist approach to the learning process. Crowder views himself as an advocate of differentiated psychology. But a recognition of the importance of the student's individual characteristics does not constitute a new approach and a new understanding of the process of learning. On this question there are no differences between Crowder and Skinner. Their differences concern the role of student answers in the process of learning and the significance of individual characteristics (219). For Skinner an answer is a component part of the learning process; it is produced in order to be reinforced and strengthened. This is why Skinner emphasizes the need for constructed answers which students must not merely formulate in their minds (implicit forms of answers) but write in, i.e., give an explicit form of answer. An answer is a verbal response that from the first must be performed correctly and then reinforced and thus strengthened. Naturally, under such an approach an erroneous response is undesirable: it does not lead to a reinforcement of correct responses. And Skinner opposes erroneous responses.

Crowder, on the other hand, views answers as a means for taking into consideration the individual characteristics of students in order to adapt programmes to each student. This is why he does not require that students construct their answers and is not afraid of errors. Nevertheless, the basic learning scheme employed by Crowder is constructed in the same way as in the case of Skinner: the objective of learning is to obtain a correct answer (which is a required part of learning); it is immediately reinforced and serves as the only indicator of learning. The difference lies in that Skinner guides the student towards the correct answer by relying, as has been noted, on a system of procedures that are identical for all students, while Crowder does it with the help of individualized procedures. The programmes drawn up in accordance with the suggestions of Crowder provide for an individualized approach to learning not only by the rate of progress but by the level of difficulty as well.

This is achieved by orienting the programme to better students and providing a problem after each frame together with a set of answers of which only one is correct. Insofar as possible, answers are selected in such a way that incorrect answers include typical student errors which are known from past practice.

The selected answer determines the further progress within the programme: if the student has selected the correct answer he receives a confirmation of the correctness of his selection and sometimes praise as well and passes to the next part of the programme. If, on the other hand, he has selected a false answer he will be directed to one of the branches of the programme, depending on the nature of his error. There he will receive additional explanations and sometimes additional problems as well before returning to the initial frame at which he had committed an error, and is again asked to select an answer from proposed alternatives. Thus, students move along the programme through different paths: the better ones proceed along the basic system of frames while others for which that path is difficult enter particular additional systems of frames constituting side branches in relation to the main programme.

Crowder ignores the cognitive activities leading to correct answers as well; he is not concerned in the manner in which learning takes place and merely wishes to know whether it does in fact take place. This is determined by the correctness of the answer selected by the student.

While Crowder, unlike Skinner, does not rely in his programmes on consistent application of any particular model of learning, in fact, he implements the behaviourist approach to learning and develops it in accordance with the same scheme: stimulus-response-reinforcement.

At the same time, the behaviourist laws of learning are not implemented as rigorously in the works of Crowder as in those of Skinner: many elements of his programming are based on common sense and practical experience. Crowder does not propose an explicitly formulated system of principles. "The writer of intrinsic programs is no more committed to any specific theory of learning than is the writer of any other type of expository text. The writer may regard good expository writing as primarily an art" (220, p. 252). It should also be noted that he finds in Skinner's system an explicit application of the theory of conditioned reflexes to the human learning process and considers this to be a naive approach that does not correspond to the human objectives of learning. In his opinion, branching programmes meet the specific characteristics of human learning more adequately. While we agree with this it should be noted that the element of "humanization" in Crowder's programmes does not extend beyond the framework of a behaviourist understanding of the process of learning since attention is concentrated on the external responses of students which are in fact the objects of regulation. The cognitive activities of students are not programmed and their contents in the process of learning are not controlled. Accordingly, in this system of programming, as well, these activities do not appear as an object of regulation.

While Crowder's programmes do not guarantee the development of rational types of cognitive activities they impede this to a lesser extent than do Skinner's programmes. Because of the rigour and simplicity of their requirements, the latter largely limit the cognitive activities of students to perception and memory. Crowder's programmes, on the other hand, frequently present problems that require thinking. If students have developed the required procedures of thinking activity they are able to apply them. If they have not developed them, they may develop them accidentally by relying on additional explanations.

Thus, by giving more freedom to students and presenting to them more strict requirements than in the case of Skinner's programmes, Crowder's programmes open greater possibilities for an unregulated development of procedures of thinking activities.

An analysis of these approaches to programmed instruction shows that the behaviourist approach is typical for programmed instruction in the United States of America. Such an approach is also characteristic of many other countries which have borrowed the corresponding principles of programming from the United States. The prevalence of the behaviouristic programmed instruction is shown not only by programming practice but also by approaches to research studies in that area.

§ 5. Major Approaches to Research in the Area of Programmed Instruction

Research activities in the area of programmed instruction emphasize the following:

1) the further development of the principles of programming learning proposed by Skinner;
2) a search for methods to implement them;
3) an experimental verification of the influence of the specifications described by Skinner on the effectiveness of instruction;
4) research into unsettled problems that represent a watershed between individual approaches to programmed instruction.

Without seeking to provide a survey of studies in the area of programmed instruction let us consider major areas of research activities and the corresponding findings.

1. The Role of Logical Sequence in the Presentation of the Materials Studied

Skinner's requirement that the presentation of materials under study be ordered logically has led to research activities concerned with a) developing methods for identifying the logical structure of study materials and for establishing the way in which they should be ordered; b) a clarification of the influence of logical rigour in presenting study material on the effectiveness of instruction.

The development of methods for identifying logical structures of the individual subject and for introducing ordering into its study has produced the Ruleg system already mentioned earlier, which was proposed in 1960 by J. Evans, L. Homme, and R. Glaser. In accordance with that system rules are identified within the subject that are entered into a matrix that in turn defines relations among these rules (227).

An analysis of these relations makes it possible to locate the material to be studied in a logically structured sequence. It is assumed that study will proceed in accordance with a deductive method: initially a rule is given and this is followed by an example. That system also contains concrete instruction on the embodiment of the principle of attenuation of prompts in the programmes.

Subsequently, the Ruleg system has been employed repeatedly in other studies. In particular, C. A. Thomas, I. K. Davies, D. Openshaw and Y. B. Bird relied on that system in identifying principles for designing matrices of basic rules relating to individual subjects and for constructing so-called flow diagrams modelling the structure of individual subjects and programmes for studying them (315).

A reliance on the framework of symbolic logic has also been proposed in order to identify the logical structure of a subject (308). In addition, Stolurow also considers it essential to make use of such methods as the method of distinction, the method of coincidence, the method of parallel changes, and the method of residue in designing the logical structure of programmes.

Essentially the *method of distinction* relates to the requirement that not only examples that illustrate the phenomenon being studied (positive examples) be included in a learning programme but also examples in which this phenomenon is absent (negative examples). In such cases examples may be presented either simultaneously or sequentially but their differences must be emphasized.

The *method of coincidence* refers to the introduction into learning programmes of a sequence of examples that illustrate the concept or principles being studied. Variants of positive examples must be perceived in such a way that what is common to them, that is, the element that they illustrate must be evident to the student.

The *method of parallel changes* is employed to illustrate the interdependence between different variables. For example, a number of examples may show that an increment in one variable leads to an increment in the value of an associated variable.

The *method of residue* presupposes that a problem is posed to the student and that several ways for solving it are indicated that initially appear to be equally appropriate. With the help of the learning programme, however, the student gradually establishes the falsity of all solutions except one, namely, the "residue". In the view of Stolurow, as students reach the final relation ("residue") they experience it as their own discovery (308, p. 63).

Stolurow also identifies four possible types of relations among stimuli and responses, namely: a) one-to-one relations; b) one-to-many relations; c) many-to-one relations; d) many-to-many relations. An example of the first type is provided by the relation between an object and its name. The relation of a concept of a genus to that of a species in which the former is a stimulus and the latter a response, provides an example of the second type. Conversely, if the species operates in the role of a stimulus and a genus in that of a response this will illustrate the third type of relation, while the fourth type is illustrated by the relation between the symptoms and causes of an illness. Stolurow also notes the importance of taking into account the associative possibilities of the materials to be structured; preceding materials may influence the study of subsequent material either positively or negatively.

Another trend of research into the logical structure of materials being studied is aimed at identifying the influence of the logical sequence of designing a teaching programme on learning effectiveness.

It has been shown in some studies that a logical ordering of such materials leads to a better assimilation (232). Attention has also been directed to the importance of an understanding by students of the principles on which the design of the programme is based: an identification of those principles and their communication to students leads to substantial improvements in the assimilation of materials (308).

In most studies, however, one does not find a significant influence of a logical ordering in the presentation of material on the quality of its assimilation: learning programmes designed in terms of a set of logically unrelated frames have given the same results as programmes in which these frames were presented in a logically ordered way. In particular Evans, Glaser, and Homme have shown that even the use of the Ruleg system for designing logically justified programmes does not result in a greater effectiveness in learning (226). Similarly the experiments of K. V. Roe, H. W. Case, and A. Roe have shown that the use of logically designed sequences does not exert a significant influence on either the number of errors that are recorded on the part of students in a process of learning or on the time required for studies and the number and duration of check tests. These authors offer the following explanation: in the case of instruction through unsystematized texts students find themselves in problem situations, their attention becomes more acute and as a result a better assimilation is achieved than in the quiet reading of logically well-ordered material (290).

It should be noted that these authors do not deny the role of understanding material in facilitating its assimilation. They believe that in studying disjointed fragments students do arrive at an understanding, but that the path leading to such an understanding is different from that in the case of studying logically sequenced programmes.

In studying the specific characteristics of assimilating different sequences of frames, Stolurow has concluded that while different sequences frequently lead to similar results, they nevertheless present different requirements to the students: some of them call for the development of general intellectual abilities, while others call for specific abilities associated with an ability to reason within a given area of knowledge (307).

Finally it has been established that the selection of a particular sequence depends on the students' abilities. R. F. Mager let students themselves decide the sequence in which materials should be learned. It was found that in some cases the sequences established by the students possessed common features, while in others they literally varied from one student to another (265).

Thus experimental studies of the role of logical rigour and ordering in the presentation of materials for assimilation have not produced clear results. If one compares the groups of data that were mentioned it may be seen that in fact a role was played by still another factor, namely, the contents of the cognitive activity carried out by students.

In particular, the authors themselves explain the greater effectiveness of material assimilation in the case of unsystematized texts explicitly in terms of the nature of the students' cognitive activities. It is not possible to understand the findings produced by experimental studies without considering that factor.

2. The Size of Instruction Steps

A considerable number of studies is concerned with establishing the dependence between the size of an instruction step and the time and quality of learning. Above all it should be noted that the concept of the "instruction step" itself is interpreted differently by different authors. In some cases it refers to the division of materials into doses (frames). Naturally the magnitude of the instruction step will be inversely proportional to the number of frames in the programme: when a given volume of material is divided into a larger number of frames, each step will be smaller, and converse. Such an approach to interpreting an instruction step assumes that the frames are identical in terms of their functional significance. Usually such an interpretation of the step is found in the analysis of the programmes of the Skinner type, in which frames are more homogeneous than they are, for example, in the branching (intrinsic) programmes of Norman Crowder.

In other cases the magnitude of an instruction step is determined by the relative difficulty of concepts and of relations among concepts that are employed in the given part of the material. In still a different interpretation an instruction step refers to the magnitude of the answer that is expected ("response size"). In a fourth group of cases which is associated only with programmes in which multiple-choice answers are provided, a step refers to a number of attempts that a student makes in arriving at the correct answer. Finally some authors associate the concept of an instruction step with the incremental difficulty in passing from one programme frame to another, or else, the extent to which promptings are reduced as one passes from one frame to another (263; 315; 304; 236).

It may be seen that in the first two cases the concept of an instruction step is associated with stimuli, but different aspects of stimuli are viewed as criteria: under the first approach it is the external aspect of a stimulus (the length of the text); under the second it is the text's content accessible to students; in the third case the concept of an instruction step is associated with responses, but the criterion relating to the size of the step remains unclear. For one can interpret the meaning of "response size" as a purely external characteristic (for example, the number of letters that a student must enter into a frame containing omissions). But the response size may also refer to its degree of complexity. The fourth and fifth conceptions of an instruction step are associated with the way in which students arrive at an acquisition of knowledge, that is with the execution of the given response.

The interpretation of an instruction step as the response size corresponds most closely to the behaviourist approach to learning, for only the external response is taken into account. The more the number of individually-formulated elements into which a programmed external response is divided the smaller the instruction step, and the more the number of steps required for developing such a response. And conversely, the less the number of elements, the larger the instruction step, and the less the number of steps in developing the response.

It is by no means always clear in experimental studies on the influence of the size of instruction steps precisely what the authors have in mind.

In most cases that concept refers to the size of the frame (the number of words in a frame). Implicitly, moreover, it is assumed that larger frames present more knowledge and call for a larger final verbal response. Yet it is not difficult to show that the number of words determine neither the volume of knowledge contained in a portion of the material, nor the relative difficulty for students to acquire that knowledge, nor the character of the cognitive activity that is required by the contents of each frame. This is why we believe that an instruction step should not be identified with the number of words in a frame. It seems more appropriate to view that concept in terms of the new knowledge (ability) that is introduced into the teaching-learning process. Accordingly the size of the instruction step should be determined not by a number of words in a frame, but by the number of new concepts, new relations, and new attributes, that each frame introduces simultaneously into the teaching-learning process.

In viewing an instruction step as a response learned by a student (or else as an increment in knowledge and abilities, as we would prefer to say) we may refer to it as a "step in knowledge acquisition" (increment in knowledge). Since students do not assimilate all knowledge that is introduced into the teaching-learning process, instruction steps will not correspond to steps in knowledge acquisition. As for the interpretation that associates instruction step with the manner in which students reach the corresponding objective (increase in acquired knowledge), this seems to be inappropriate for it would refer to an instruction cycle rather than a step. It seems to us, however, that if one views the teaching-learning process in terms of learning, that is, of students' cognitive activities, it is possible to introduce the concept of a "step in learning". This should refer to a student activity carried out without control (without feedback) over its input elements, i.e., an activity that is accepted as an elementary operation.[1] To conclude, a survey of studies concerned with steps in instruction shows that that concept is non-unique and calls for further discussion.

Let us now turn to studies that are concerned with the influence of the size of steps in instruction on the effectiveness of instruction. They have shown that in most cases the best results are produced by instruction in terms of small steps (with regard to the particular meaning of the concept of a step that is employed by the corresponding author) (262; 225; 215).

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[1] An attribute of human elementary operations is the ability to perform such operations without errors. For further details, see: L. N. Landa, *Algoritmizatsiya v obuchenii* (Algorithmization in Instruction), (81).

The best results were obtained in cases in which students were themselves able to regulate the size of steps.

In a number of studies the size of steps did not influence outcomes. At the same time it was noted that instruction in terms of small steps requires much more time than instruction in terms of large steps (216; 304). In that connection the problem has been posed of establishing experimentally the optimal combination of step size and time expenditures that produce an effective assimilation (216). A number of authors have expressed the view that a system of small disjoined frames cannot be effective, since students then do not acquire a conception of connections between individual elements. In particular, H. A. Thelen notes that students must have a conception of the overall model, and that it must be presented to them as a reference (313). It is therefore proposed to employ survey tables in programmes in which basic formulae, basic definitions, and other general data are presented. It is also proposed to provide summaries following individual programme sections (236).

3. The Relative Effectiveness of Different Forms and Types of Answers (Responses)

It has been noted that in accordance with his general approach to instruction B. F. Skinner has insisted on the use of answers that are constructed and explicit, since, in his view, multiple-choice and implicit answers do not require an active execution of the response that is being developed (or else of its elements). Such answers may also lead to errors. Other representatives of the behaviourist approach to instruction, however, do not consider that requirement to be essential to effective instruction. In connection with the discussion of that problem an experimental study was carried out to test the significance of that requirement.

Comparisons of programmes with constructed and multiple-choice answers have shown that there is no significant difference in their effectiveness. In particular, following an analysis of studies carried out by different authors, H. F. Silberman notes that in five out of seven studies concerned with such comparisons there was no difference in effectiveness. In two cases the constructed answer was more effective (293). But then in another study, however, carried out by H. F. Silberman and J. E. Coulson it is noted that in a number of cases an external recording of answers by students reduces the effectiveness of their work (217).

A question naturally arises on the reasons for such differences in findings. At first it seems that they make invalid the view that instruction should be an active process: for whether a student designs his own answer or selects one from a prepared list there is no difference in the effectiveness of instruction. In fact, however, these findings do not make invalid the principle of activeness, since that principle refers to *activities* rather than to *responses* (answers). Above all it is the content of that activity that influences the effectiveness of instruction. Accordingly definite results may be obtained only through experiments in which the content of activities is constant while the nature of the answers is varied. That condition was not considered in the studies, and the content of activities could therefore have been substantially different. Indeed, as was correctly observed in the literature, so-called constructed answers are often not associated with productive independent work on the part of students: frequently the student finds a word needed to fill in an omission in a preceding sentence or in an earlier frame (308). A number of studies also note that more time is required in the case of constructed answers than in the case of multiple-choice responses (230; 215).

We would like to add that even the use of the term "constructed answers" is by no means always justified. An answer always presupposes a question. But a request to enter omitted letters into words or else omitted words into sentences is not equivalent to a question calling for an independent answer. It should also be noted that omissions are not based on a sufficiently clear criterion: many omitted words do not carry the specific information that represents the subject of assimilation. It has already been noted, for example, that in providing for the assimilation of a new concept its full definition is first presented, and then a sequence of frames is produced in which each word in the definition is omitted in turn. Such a logic of omissions is justified in a specific case, namely, when a word-by-word memorization of the text is desired.

Thus such a form of answering does not itself provide for an active initiative on the part of students, directed at the object of assimilation. And conversely, the multiple-choice answers do not automatically impede initiatives on the part of students. Indeed, let us assume that a student is given a problem to establish the part of speech to which the word "whiteness" belongs. The proposed answers include all possible parts of speech. In order to select the correct answer the student need not necessarily follow the mechanical approach of comparing all variants. He may carry out an act of recognition by establishing that the necessary and sufficient attributes of a noun are present in the word "whiteness". Since that activity is directed at the concept's essential substance the effect of performing it will be much higher than that of writing down one of the omitted words into the definition of a noun (a constructed answer).

It is not the form of the final answer that determines the measure of activity of students, but the nature of activities leading to an answer. It is this which should be programmed and regulated in the course of the instruction process.

As for the second danger attaching to the multiple-choice answers, namely, the possibility of memorizing and subsequently repeating erroneous answers, that danger, too, need not take place. It is real in the case of forms of instruction in which memory is employed as the principal means for assimilating knowledge, and in which there is only a concern for external responses as well as a neglect of the manner in which they are developed. Conversely, in forms of instruction that provide for an understanding of essential relations within the material being assimilated and for developing thinking procedures that make it possible for students to arrive at the required answer independently the danger of reproducing erroneous answers is greatly reduced.

It is true that any subject contains material that may be assimilated only at the level of memorization. An example is provided by the names of the phenomena that are studied, dates, proper names, and the spelling of words that do not fall under rules of orthography. In such cases erroneous examples, when presented in lists of proposed answers, represent a serious danger. Even then, however, the multiple-choice approach may be admissible if one follows the following condition: that only those types of answers must be proposed that are applicable to solving problems of the given type. The number of answers that are proposed must then cover all cases to be assimilated. This may refer, for instance, to parts of speech, members of sentences, and auxiliary verbs in the English language. An illustration is provided by the example mentioned earlier relating to the recognition of parts of speech. In such cases the students must remember all proposed variants (parts of speech). The system then contributes to such an acquisition of material. Similar problems may relate to the recognition of members of sentences. In such cases all possible members of sentences should be listed as proposed answers. Choices of this type do not carry a danger of encouraging the memorization of false answers. On the contrary, they contribute to more rapid assimilation of specific cases and do this in a systemic context.

Similarly, the multiple-choice approach cannot produce any harm in cases in which none of the proposed answers constitute an object of assimilation. This applies above all to numeric and letter answers that are employed in solving problems.

Thus in carrying out particular types of cognitive activities the multiple-choice answers may be effectively employed. But since the activities that lead to a particular answer were not programmed in the studies under consideration and were therefore not taken into consideration, it remains unclear in what cases one should prefer the multiple-choice answers and in what cases one should prefer constructed answers.

A large number of studies are also concerned with the extent to which answers are explicit. In particular, the relative effectiveness of three types of student responses were studied experimentally: a) writing down omitted words (explicit open answers); b) a mental filling of omissions (nonexplicit hidden responses); c) the reading of texts without omissions (the reading of prepared answers).

The corresponding findings have led most specialists to believe that it is not important to require explicit answers, for it was apparent that the nonexplicit form of answers was equally effective (209; 254; 233; 262).

Moreover, a number of cases have shown that better results are obtained when nonexplicit forms of answers are employed, or else when students do not provide any answers at all but merely read the programme (306; 209).

H. F. Silberman has analyzed the findings of fifteen studies concerned with a comparison of explicit and nonexplicit answers. He notes that no difference was found in nine of these studies, that in four cases the outcome of assimilation was better under a nonexplicit form of answers, and that only in two cases was the effectiveness of explicit forms greater (293). It was also noted in all studies that the explicit form of answers calls for more instruction time (309; 226).

A number of researchers, however, believe that the measure of explicitness of answers does influence the effectiveness of instruction. In particular J. D. Krumboltz and R. G. Weisman note that the role of the form of answering was not revealed because in all these studies short programmes were used, possibility for errors was not known, and the quality of assimilation was established only immediately after the completion of a programme while the subsequent state of knowledge was not studied. In their studies, too, no difference was seen immediately after the completion of the programme. A verification after two weeks, however, has shown that the group that had been required to provide answers in explicit forms was more effective (254).

Glaser and his co-authors believe that the significance of explicit forms of answers depend on such conditions as the probability of a correct answer. Briggs mentions the difficulty of the material to be studied as one of such conditions. Together with his co-authors he carried out nine series of experiments, in which aside from differences in the degree of explicitness of answers the programmes to be mastered had three types of difficulty. It was found that explicit answers increased effectiveness only in those cases in which the programmes were of average difficulty. In the case of simple programmes explicit answers led to a decline in the level of assimilation. It was also found that the group that was required to provide explicit answers was somewhat more effective in a test in which the content was close to that of the teaching frames (209).

Stolurow and Walker (309) believe that the findings relating to the role of explicit (written) answers place in doubt the importance of activeness in instruction, for some of the data indicate that it impedes it. It has already been noted, however, that one should not associate activeness in instruction with the filling of omissions in a programme. Thelen is right in noting that Skinner's requirement of activeness is too ambiguous. The decisive link, he adds, is that activity (activeness) of students which brings them to the objective of the instruction process. The task of instruction programmes is to teach them to achieve such objectives in the best possible way. But the writing of answers (explicit forms of answers) does not always contribute to this (313).

In this way studies of that requirement of Skinner as well have shown that it is insufficient to consider only external responses, and the students' cognitive activities, too, should be considered. The role of written (explicit) answers in the instruction process is primarily determined by the following conditions.

First, by the relation of answers to the students' cognitive activities: if they represent a recording of activities that correspond to the objective of the instruction process then its writing may play a positive role. If, on the other hand, the recorded activity does not lead to the specified objective, then explicit answers do not contribute to increasing the effectiveness of assimilation.

Second, by the relevant stage of instruction: at the beginning of the assimilation process an external recording contributes to the performance of new types of activity, but at later stages it impedes it.

4. The Principle of Prompting in Instruction

The principle of prompting, introduced by Skinner in order to gradually guide students towards the correct answer, was also subjected to special studies. Promptings are viewed as a specific type of stimuli that increase the probability that students will arrive at the desired answer. This poses the question of search for the most effective types of prompting. Skinner distinguishes between semantic and formal prompting. Semantic promptings rely on a utilization of students' "worldly" knowledge, while formal ones are based on such elements as rhymes, external associations, and common features in grammatical structure (302).

The following frame from a course in physics is an example of a semantic prompting: "Just as smoke rises, warm air will also...." The student is expected to insert the word "rise" (263). As an example of a formal prompting let us turn to another frame from the same programme: "The higher the temperature, the faster the molecules move; the lower the temperature, the ... they move" (*Ibid.*). A description of specific forms of both types of promptings is given in the studies of D. Smith (303), A. Lumsdaine (264), Skinner and Holland (302).

Skinner and Holland note, for example, the following classification of prompts:

a) those that are based on the relationships between examples and definitions. Definitions are given in full while examples are given with omissions. Thus psychology students are given a definition of a reinforcement in the following words: "A technical word for reward is reinforcement." This is followed by the following sentence: "To reward an organism with food is to ... it with food." It is assumed that the word "reinforcement" suggests the word "reinforce";

b) a presentation of initial, final or other letters from a word that students are expected to fill in;

c) rhyming prompts: "5 times 5... (Response: 25);

d) the use of well-known expressions. In such cases the required word is reproduced through a habitual association with another that is given. For example, in studying the concept "reflex" in a course in psychology the student is given the sentence: "A doctor taps your knee (patellar tendon) with a rubber hammer to test your....";

e) the use of associations of opposite concepts. For example, at first a definition of a positive reinforcement is given. Next a formally similar expression is employed to define a negative reinforcement but this time with the word "negative" omitted.

Without citing additional specific types of promptings let us note that Skinner does not apply any limitations to either their form or content. In referring to Skinner's prompting techniques as tricks J. Wohlwill observes with irony: that as in love or war all means are fair in programming if they lead to a correct answer (325, p. 141).

Experimental studies of the role of prompts in instruction have been carried out by G. A. Kimble and J. J. Wulff (253), S. R. Meyer (271), G. Angell and A. A. Lumsdaine (200), among others. As in studies of other principles these produced no definitive findings.

Silberman cites the findings of twelve studies in which instruction without prompts was compared with instruction relying on prompting, namely with a procedure in which frames were displayed together with corresponding answers. It was found that in seven cases instruction was more effective, when prompting was employed, no differences were recorded in three cases, and in two cases the results were better when prompts were not employed (293).

In view of most authors, however, instruction with prompting is more effective than without it. Its effectiveness especially marked in cases in which it helps avoid typical errors. In this connection Meyer, who studied the role of prompting in the assimilation of the English language, came to the conclusion that syntactic prompts are more effective than semantic prompts, while orthographic prompts are not effective at all (271).

It is noted in the literature that the problem of prompting in instruction calls for additional studies in order to identify both the most effective types and the necessary quantity and intensity of prompting (288).

As in the analysis of the earlier groups of studies the ambiguous nature of the findings cannot be understood unless one considers particular students' activities. Objectively only those prompts play a positive role in the teaching-and-learning process that help students carry out activities that correspond to the specific characteristics of the subject being studied and the goal of learning.

The fundamental shortcoming of the approach that has been considered derives from the fact that attempts are only made to help responses rather than activities. It is possible that in some cases particular types of prompts will guide students to the desired activity. They will then contribute not only to a memorization of the ready answer but to an understanding of the way that leads to that answer and will thus increase the effectiveness of the learning process.

5. *The Principle of Reinforcement in Instruction*

A large number of studies are concerned with the principle of reinforcement, which plays a central role in the behaviourist theory of learning.

According to that theory reinforcement is expected to carry out two functions, namely: a) to increase the probability of obtaining a response; b) to create a readiness on the part of students for further instruction, i.e., to develop positive motivation for learning activities.

In referring to the specific characteristics of reinforcement in the context of human learning Skinner observes that elements of reinforcement are contained in the subject-matter itself that is being studied. "Children play for hours with mechanical toys, paint, scissors and paper, noise-makers, puzzles -in short, with almost anything which feeds back significant changes in the environment and is reasonably free of aversive properties. The sheer control of nature is itself reinforcing" (301, p. 108). Skinner emphasizes that taken by itself the power of reinforcement is not very significant: when properly used even the weakest reinforcement may be effective (301).

In cases in which the natural reinforcement associated with the properties of the object itself is insufficient, Skinner adds, it is necessary to apply other means of reinforcement (*Ibid.*). In this case, as has already been noted, he proposes the use of correct answers that are displayed to students after they have recorded their own. Since the implementation of other programming principles proposed by Skinner provides for a high level of probability of correct answers, as students check their answers they are gradually persuaded of their correctness. That, in turn, in his view, produces a feeling of satisfaction with the results of one's activities that contributes to a consolidation of correct answers and to a readiness to proceed with further learning.

Basing himself on findings relating to the training of animals Skinner has listed the requirement that reinforcements be used immediately and frequently. He asserts that an interval of even several seconds between an answer and a reinforcement reduces significantly the reinforcement effect. He considers that each step in instruction should be accompanied by reinforcement. "By making each successive step as small as possible, the frequency of reinforcement can be raised to a maximum, while the possibly aversive consequences of being wrong are reduced to a minimum" (*Ibid.*, p. 109).

These requirements of Skinner are by no means shared by all representatives of the behaviourist approach to instruction. There were many discussions concerning the problem of reinforcement, and they continue today. The principal issue concerns the very need for reinforcement. Opponents cite instances of random and latent instruction that occur without reinforcement (279).

The second problem under debate concerns the nature of reinforcement and its function in the learning process. There one finds at least three points of view. Initially the role of reinforcement was interpreted as an action of the current state of the nervous system on its preceding state, which is presumed to reinforce connection between stimuli and responses (319): later the function of reinforcement was viewed as one of attenuating the need associated with reinforcing stimuli (247; 248; 249). A later point of view denies that reinforcement possesses a direct consolidating effect and interprets its function as one of either feedback relation, or of motivation, or both (240; 277).

Doubts have also been expressed concerning the emphasis on frequent and immediate reinforcement. Finally the relative effectiveness of various types of reinforcement is considered.

All these problems have been reflected in experimental studies. Research on the relative effectiveness of various types of reinforcement has followed a number of approaches. First, comparisons were made of various types of positive reinforcement. In some cases the relative effect of "material" reinforcement (candies, money) and "ideal" reinforcement (praise, a knowledge that the answer is correct) was established (281; 275), while others examined the role of the various forms in which a specific type of reinforcement was conveyed. For example, in the studies of Moore and Smith it was found that one group of students compared their answers with the ones given for purposes of comparison and inferred that their answer was correct. In another group the answer was not shown to students but a light signal was employed to indicate to them that their answers were in fact correct (275).

Second, there were comparisons of the effects of positive and negative reinforcement, namely of praise or condemnation and of an admission of students to groups ranked in terms of their achievements (259).

Finally, the basic significance of reinforcements was studied: comparisons were made of instruction activities with and without reinforcement (274; 275; 281; 246).

As in the case of studies of the other principles, the findings remained unclear: not only was no significant difference found between various types of reinforcement, but it was not even established that reinforcement itself is clearly significant. Thus in the study of Homme and Glaser (246), students were not given correct answers with which they could compare their own. But this did not reduce the effect of instruction. They did not feel the need to compare their answers since they were certain of their correctness. In fact the study carried out by Moore and Smith (274) showed that students who did not receive reinforcement obtained somewhat better results than those who received immediate reinforcement.

In our opinion these findings should not be interpreted as a proof that reinforcements are not significant; they merely indicate that a knowledge of the correctness of one's answer (or else praise) does not always perform a reinforcing function. The correct application of the principle of reinforcement to human activity is not as simple and linear as in the case of animals. It is well known that even in the case of animals reinforcement is effective only in those cases in which animals feel a need for it (this is why reinforcements based on food are employed with animals that were previously deprived of food).

In our opinion when it is applied to man the effectiveness of reinforcement depends on the relations of that influence to the motivations and the objectives of the person's activities. A knowledge of the correctness of one's own answer may appear as a reinforcement only in cases in which, first, the acquisition of knowledge is used by students not only as an objective but also as a motivation for their learning activities, and second, when students are not certain of the correctness of their answer and require a feedback relation (169). Stolurow has expressed a similar point of view, namely, that "one condition determining the effect of reinforcement is the extent to which the reinforcing event relates to the motivation of the learner" (308, p. 78).

The corresponding findings have thus shown that the reinforcement of responses should be distinguished from their confirmation (275) and that confirmation performs a reinforcing function only under specific conditions (211). In this connection some researchers carried out experiments in which together with a confirmation of the answers special reinforcement actions were introduced, such as general praise, differentiated grades, small gifts, etc.

These experiments, too, did not lead to any conclusive findings. In some cases it was found that a positive reinforcement (approval) facilitates the process of learning, while a negative reinforcement (condemnation) impedes it (259). Other authors have found that additional reinforcing influences do not lead to increases in the effectiveness of instruction. Thus, for example, 200 students participated in an experiment carried out by I. L. Evans. One half of them received only a confirmation of the correctness of their answers, while the second half was also given a monetary reward. No difference was found in the effectiveness of instruction in these two groups. Similar results were obtained by M. Alter and his co-authors (198), as well as by J. J. Sullivan and his co-authors (312).

In fact in some of the cases students who received the material reward displayed a lower effectiveness in instruction than those who received only a confirmation of the correctness of their answers. In particular, these were the findings of W. A. Hillix and M. H. Marx in teaching sensomotor reactions to 60 students (241). Similar results were obtained by H. H. Marshall (266).

Generally, studies concerned with a comparison of the effectiveness of various types of reinforcement show that their role in instruction may be interpreted only after their function in the activities of the students has been established.

Thus it may be assumed that in the case of the group in which it was found that a monetary reward did not lead to increased achievements reinforcement only performed the function of feedback. Only such an interpretation explains why no difference was found in groups in which only the correctness of answers was confirmed, in which monetary rewards were given and in which both took place. In the first case the feedback relationship was carried out in a direct form, while in the second it was mediated: the student was not able to compare his answer with the correct one, but having received a reward he interpreted this as a confirmation of the correctness of his answer. In the third case both forms of feedback were present. But it is sufficient for the student to have one form, and accordingly the additional element did not produce any effect.

Furthermore, the experiments in which instruction without confirmation of the correctness of answers yielded the same results as instruction with such a confirmation indicate that a feedback relationship leads to an increase in effectiveness of instruction only in those cases in which it is needed by the student. In working with programmes of the Skinner type students generally fill in the omissions in frames without difficulty and do not always experience the need to verify the correctness of their answers; they are frequently certain that they are correct. Naturally under such conditions there is no need for feedback and accordingly its absence does not reduce the effectiveness of work.

The corresponding experiments cannot be viewed as studies of effective reinforcement and of the relative effectiveness of its various types: there is no evidence that such a role was actually performed by the influences being studied. On the contrary, the findings would appear to indicate that the influences did not operate as reinforcements.

Experimental studies have been carried out to verify the significance of Skinner's requirement that reinforcements be conveyed immediately following a student's response. Skinner and his followers assert that a delay in reinforcement by only a few seconds leads to a substantial reduction in effectiveness. In some cases, however, experiments have shown that even substantial delays in reinforcement do not reduce the effectiveness of instruction (226; 207; 274; 311). More than 200 students of psychology participated in the experiments carried out by L. E. Bourne and C. V. Bunderson. The problem was to classify a number of geometric figures into four classes. The work proceeded in accordance with the method of "trial and error": students selected a figure and arbitrarily assigned it to one of the possible classes. Subsequently the class to which the given figure belonged was stated. One group of students was given that information immediately following their answer, another after four seconds, and a third after eight seconds. A comparative analysis of results for each group has shown that there was no significant difference in the effectiveness of work in each group.

Similar findings were obtained by P. G. Sturges, who compared the effectiveness of immediate reinforcement with reinforcement after a delay of 24 hours. No difference in the effectiveness of instruction was established, even though the test was carried out on two occasions, namely immediately after completing an experiment and then a week later.

Other studies, however, have found that a delay in confirming the correctness of an answer exerts a significant influence. But while some researchers found this influence to be negative others found it to be positive. Thus in an experiment carried out by R. L. Leathers in which 100 ninth-grade high school students participated the best results were obtained by a group in which immediate confirmation of correct answers was provided (258).

Conversely, in the experiments carried out by R. Atkinson for a group of fifteen students who were asked to memorize meaningless associations, a delay in the confirmation of correct answers played a positive role (201). Similar results were found by A. I. More (276). In the case of his experiments, however, the favourable influence of postponed confirmation of correct answers occurred when delays were two and a half hours and one day. Delays of four days produced less favourable results.

The inconclusive nature of these data concerning the role of immediate reinforcement indicates that results are primarily defined by the *function* that reinforcing stimuli introduce into the student activities. The authors based their studies on the assumption that the function of that stimulus is reinforcement. As has been shown above, however, this is by no means always true. Accordingly such findings cannot be viewed as demonstrating the role of delays between responses and the conveying of reinforcements.

Experimental studies were also carried out to test the effects of Skinner's requirement that reinforcement be applied to each small step.

As in preceding cases the findings were not conclusive. According to the data of some of the authors a reinforcement of each step in instruction is not a necessary condition for learning: frequently the person knows that he is right without receiving any confirmation of the correctness of his answer from others (228; 288). G. Sax (292) carried out experiments in which he compared two variants of the frequency of reinforcement: a) a reinforcement of every step; b) a reinforcement of only a half of the steps. No differences were found between the groups, either with regard to the number of trials required to assimilate a correct response, nor in terms of the number of errors made in verifying the quality of assimilation following the completion of the instruction process.

Similar data were found in studies carried out by J. D. Krumboltz and R. G. Weisman (255). H. A. Thelen notes that even the training of rats does not require frequent reinforcement (313).

On the other hand, D. C. O'Connell, who compared the effectiveness of instruction in the case in which every step was reinforced with the case in which only 60 per cent of the steps were reinforced, has shown that it is more effective under the first reinforcement regime (278).

S. C. Lublin (261), for his part, obtained the opposite results. His experiments are of particular interest, since the 219 students in the group were taught in accordance with the programmed textbook *The Analysis of Behavior* by Holland and Skinner (244). The first twenty-seven sections of the textbook were employed (1,144 frames) and four regimes of reinforcement were compared: a) after each step; b) for 50 per cent of randomly selected frames; c) after each second frame (for 50 per cent of systematically selected frames); d) without any reinforcement.

After a period of four weeks, during which studies took place three times a week, all students were given the same check test. The best results were recorded for the group in which the reinforcement regime was irregular. The poorest results were recorded by the group in which each step was reinforced. According to Lublin, this indicates that when working with programmes of the Skinner type students may fill in correctly all omitted elements (perform correctly all required responses) without assimilating the knowledge presented in the frames.

Thus conclusive results were not obtained in verifying the role of frequency of reinforcement either. In the literature it is noted that this is explained by the fact that a confirmation of a correct answer performs not only a reinforcement function but a motivating function as well. In particular, it is noted that in those cases in which students did not doubt the correctness of their answers a confirmation of their correctness does not perform a function of reinforcement but could still be important for motivating learning activities (226). In other words, even though a frequent reinforcement may not contribute to a reinforcement of connection it may still contribute to the development of positive motivations for learning activities.

Nevertheless the experiments indicate that a frequent confirmation of correct answers without regard for the student's need for confirmation contributes neither to reinforcement nor to the creation of a positive motivation (313; 236).

Studies carried out by V. Kulic (256; 257) and S. El Hodarie (193), moreover, have shown that the requirement that students be subjected to a systematic verification of answers then leads to a sharp decline in their interest towards their studies, that is, to a loss of positive learning motivation.[1] It was found that the correct answer (feedback) must be conveyed with due account of the actual performance of the student and of his need for such a form of control. Kulic lists four possible situations: 1) the student is certain of the correctness of his answer and the answer is objectively correct; 2) the student is not certain of the correctness of his answer but objectively the answer is correct; 3) the student is certain of the correctness of his answer but his answer is erroneous; 4) the student is not certain of the correctness of his answer and his answer is erroneous (257). Evidently in the first case there is no need to require that the student verify his answer. In all other situations this is necessary. In the second and third cases the feedback relation possesses a more perceptible motivational function.

In principle the confirmation of correct answers may apparently perform both a function of reinforcement and of feedback, as well as a motivational function. In addition the confirmation of correct answers may perform still another function: as Stolurow (308) has correctly observed in cases in which students are mistaken, the communication of the correct answer operates as a prompt.

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[1] Similar findings were obtained in the studies of T. V. Gabai (30; 31). This is described in the next section of the present chapter.

With regard to reinforcement and motivation it should be noted that a large number of researchers express doubt concerning the correctness of Skinner's assertion that a positive motivation and reinforcement are achieved by continual success independently of its scope. In this connection Thelen writes that continuous success cannot operate as a reward. On the contrary, he writes, simple steps rapidly create boredom. Success should be perceptible rather than continuous; a particular effort on the part of students should be reinforced and programmes must provide for the possibility of risk and error. Skinner's "steps" do not meet these conditions (313). A similar point of view has been expressed by R. Borger and A. Seaborne (206), as well as by R. G. Roth (291) and T. V. Gabai (31), as well as still others. It is characteristic that R. G. Roth carried out experiments with instruction on the basis of a programme prepared by Skinner himself (244).

The role of errors in the learning process is widely discussed. Most authors arrive at the conclusion that a limited number of errors is useful in instruction: the possibility of failure amplifies the reinforcing action of a correct answer and contributes to the creation of a positive motivation and also creates conditions for further progress (212; 303; 199; 256). A large number of errors (a mass negative reinforcement) produces the opposite action (217; 199; 288; 256).

Experiments indicate that the actual relation between the number of errors made in the process of instruction and the final achievement of students is not as close as could be expected. In particular, a low coefficient of error in the process of instruction does not assure that a high level of ultimate achievement will be obtained: the absence of errors in learning may be produced by an excessive reliance on prompts in the programme (288). Some researchers have proposed that false examples be deliberately introduced into instruction programmes: students must learn to see errors and to correct them since every sphere of knowledge possesses its own "traps" and sources of error (227).

It is also noted that a certain number of errors are needed in order to regulate the learning process: they are needed in order to select a programme possessing a level of difficulty that corresponds to the given student's possibilities.

The role of errors in instruction calls for further studies. It is already clear, however, that a frequent confirmation of the absence of errors in student actions without considering a number of additional factors does not solve either the problem of reinforcement (reward) or that of motivation.

Thus experimental tests of Skinner's central principle, namely the principle of reinforcement has shown that the method he has proposed for implementing is not appropriate in the case of human learning. Some researchers have come to such a conclusion already in the early years of the development of the idea of programmed instruction (205).

The key problem is to identify the conditions under which feedback would perform not only its inherent function but would also contribute to a consolidation of actions being developed and to the creation of positive motivation for learning activities among students. The studies that have been carried out indicate that feedback performs a reinforcing function only in cases in which its content is related to the motivation of students for engaging in learning activities. Feedback also contributes to a positive learning motivation in cases in which it is carried out with due account of the need of students for verifying the correctness of their actions and with due account of the objective success of their work.

In this connection it should be pointed out that in the logic of Skinner's system a comparison by students of their answer with constructed responses was introduced not in order to produce a systematic feedback relationship but for purposes of reinforcement. In the system under consideration that stage of instruction does not appear as a function of feedback: the next step in instruction does not depend on the correctness of the student's answer, i.e., the information that is gathered on the course of the process is not employed for the further regulation of that process. In other words, while in terms of content it is a feedback relation, Skinner seeks to employ it for purposes of reinforcement.

The failure to distinguish between these two functionally distinct elements has led to a situation in which the concepts "feedback" and "reinforcement" are frequently employed as synonyms. This may be found in Soviet literature (78; 91), as well as in the literature of other countries (272; 315; 252; 231).

Not only are feedback relations and reinforcement in fact distinct in a functional sense, but they may also be different in terms of content. On the one hand, reinforcement may be carried out, as have been shown, in a wide variety of ways. The obtaining of information on the correctness of action is one of them. On the other hand, feedback does not cover all cases in which an assigned course of the process coincides with the existing one. That refers to only a specific type of feedback but it, too, operates as a reinforcement only in the presence of highly specific conditions. Similarly, it is only in the presence of specific conditions that feedback may lead to a development of positive motivations for learning activity.

In short, not every type of feedback is a reinforcement and leads to the development of positive motivations for learning activity. But any reinforcement whether in explicit or implicit form also operates as a feedback relation. The efforts of researchers should be directed to a further study of the conditions under which feedback contributes to the development of positive motivations for learning activity and to the reinforcement of the knowledge that is acquired.

6. The Role of Repetition in Instruction

Repetition is one of the leading principles in Skinner's system. That principle is generally accepted in the practice of teaching. Nevertheless in the sphere of programmed instruction it has also led to discussions.

First, a question on the manner of organization of repetition arose: should one repeatedly present the same frames or else vary their content but in such a way that each time the same response be required (236). Second, the criterion for frequency of repetition is not clear; the recommendations that are proposed by individual researchers are frequently purely empirical in nature and are sometimes very subjective.

In a number of studies it was found that the repetition of material does not yield an additional effect in instruction (293; 31). As an example let us consider the findings obtained by Gabai (31) with regard to teaching elementary geometry. Instruction followed a programme of the Skinner type designed by Curtis (221).[1] It has already been noted that identical definitions were repeated tens of times in that programme. Nevertheless after learning in accordance with the programme students answered only 25 per cent of test questions correctly. These questions were concerned with the reproduction of factual material. In addition, 48,3 per cent of the students repeated the first 200 frames of the programme three times, since after the first and second trials it was found that their knowledge of the programme was unsatisfactory. But even after the third repetition most of them were not able to provide satisfactory answers to the corresponding tests. Thus a repeated study of a programme providing for repeated entries of omissions does not increase the quality of assimilation among students, since it does not lead to an understanding of the material. This is also noted by J. W. Blyth (205), R. M. Gagné and L. T. Brown (231).

All the basic principles of programmed instruction that follow from a behaviourist approach to the process of learning have thus been subjected to studies. *Experimental studies have not actually demonstrated the significance of any of them.* It seems to us that the ambiguous and often contradictory nature of the findings are explained by the fact that the role of each of these principles was verified under conditions in which the determining factor in learning, namely, the cognitive activities of students, was not controlled. The fact that the latter was not fixed explains the variety of results that were obtained in studying the role of the same principle. For the same reason significant differences were not found between the effectiveness of programmed instruction and traditional forms of teaching (307; 212; 228; 287).

Some of the studies note that programmed instruction is more effective than traditional teaching. Thus, for example, Silberman indicates in his survey that of fifteen studies concerned with a comparison of traditional teaching with programmed instruction the experience of nine authors has been that programmed instruction is more effective and of six authors that there are no differences (293).

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[1] The experiment was carried out in 1966/67 and 1967/68 in fifth-grade classes of boarding schools Nos. 7 and 36, and of school No. 1139 in Moscow.

The advantages of programmed instruction were evident in the studies of D. Porter (282), L. Homme and R. Glaser (245), D. Cook and F. Mechner (213).

A number of studies produced results that suggest that programmed instruction is less effective than traditional teaching (231; 222).

The ambiguous nature of the findings gathered in the experiments on the effectiveness of both individual principles proposed by Skinner and of programmed instruction as a whole is also explained by the fact that not all programmes were constructed in strict correspondence with the requirements of Skinner. But the principal shortcoming of these studies lies in the fact that the effectiveness of programmes was tested in terms of behaviourist criteria: that is in terms of the correctness of responses. That criterion was not sufficient, and it was necessary to establish whether these programmes contributed to the development of procedures of cognitive activities among students. This was the objective of a study carried out under our direction by T. V. Gabai for a large group of students and over a prolonged period of time.

§ 6. Behaviourist Programmed Instruction and Student Cognitive Activities

Part of the course of plane geometry developed by E. Curtis was subjected to an experimental verification. That course embodied all of Skinner's principles of linear programming (221). The programme was translated into Russian by Gabai.

The participants in the experiment included 190 fifth-grade students (from boarding school No. 7 and school No. 1139 in Moscow).[1] The results of 29 per cent of the students were "excellent" and "good". For 53 per cent of the students they were "good" and "satisfactory", while for 18 per cent of the students they were "satisfactory" and "unsatisfactory". The experiment was carried out in 1966/67 (two classes) and in 1967/68 (three classes).

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[1] The experiment at boarding school No. 7 was carried out in 1966/67, and at school No. 1139 in 1967/68. This was preceded in 1966 by an experimental application of the given programme in one of the fifth-grade classes in boarding school No. 36, which produced similar results.

Each student proceeded at his own rate. Upon completing certain sections of the material he was given a test included in the programme. When the level of errors did not exceed 30 per cent the student was allowed to proceed to the next programme segment.[1] Otherwise he was asked to repeat the segment. He was not permitted to repeat a third time.

Curtis' instructions were followed in applying operational check tests of assimilation. In evaluating the experiment's outcomes additional tests that we prepared ourselves were also given.

Curtis' tests are primarily concerned with students' ability to reproduce formulations, definitions, etc. Our own tests were aimed at verifying their abilities to prove the simplest theorems that they had studied, their abilities to employ geometric symbols, to apply general mathematical axioms (such as "if equal numbers are added to equal numbers then their sums will be equal"); their abilities to associate objects with concepts and get inferences from the fact of an object belonging to a particular class of objects. The quality of these cognitive actions was evaluated in terms of their reasonableness, the presence of conscious awareness and level of generalization. When students carried out these actions correctly with an orientation on essential attributes and provided an adequate explanation their actions were considered to be conscious and reasonable. If a correct answer was given without an explanation the action was considered to be lacking in awareness. It could still be reasonable if the student's answer was based on operations with essential object attributes.

The level of generalization of actions was established by presenting the object in new unaccustomed situations by admitting wide variations in its attributes and adding "extra" attributes. The existence (or absence) of transfers to other concepts was verified with the help of assignments in which students were given only an extensive definition of a new concept and were asked to associate it with a number of specified objects.[1]

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[1] This corresponds to satisfactory knowledge under traditional teaching.

The theorem on the equality of vertical angles was employed to verify the ability of students to carry out geometric proofs. This proof had been studied in the earlier materials. At first students sought to prove that theorem on the basis of a verbal formulation and of instructions alone. When they were not able to do this they would turn to the next page where an addition to a verbal formulation of the theorem, a diagram, was presented as well as a written statement of what was given and what had to be proved and also some prompts on the proof's basic principle ("Use the definition of a flat angle and the axiom: 'If from equal numbers one subtracts equal numbers ...'.").

Let us pause to analyze the learning process. At first children displayed great interest in their studies and a desire to study. But already after a few days they became indifferent and then developed an antagonistic attitude towards assignments. In order to maintain a working discipline within the class it was necessary to resort to extreme administrative measures. [2]

It was evident that the children viewed studies with books as tiring. At the beginning of each lesson they would start to study only after a delay. They paid attention to their text for about twenty minutes, but after that they found it difficult to continue studies in accordance with instructions. Cases of a mechanical copying of answers were not infrequent.

In filling in omissions students did not always understand what they were being asked to do. They were frequently guided by the grammatical associations of words rather than by their meaning. For example in a sentence "... circumference is a straight line passing from the centre to a point on the circumference" fifth-grade students entered the words: "In a round", "A point on a", "Around a", etc.

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[1] We used these assignments on many occasions in experimental teaching of fourth- and fifth-grade students in order to establish the quality of the assimilation of concepts that were developed by the method of stage-by-stage development of mental actions. These students answered them successfully.

[2] Studies were rigorously scheduled, grades were entered systematically into class records and into each student's daily report. In this way this became a required subject for each student.

The questions that were asked by students in the course of their studies reflected their difficulties in understanding the meaning of portions of the programme and their relation with each other; most often they related to the procedure for working with programmed material or represented a request to explain a particular word or expression that was not understood. It was only infrequently that questions related to the substance of the matter, and it was only in fulfilling tests (in which answers were omitted) that students began to ask questions on the content of the concepts being studied and on methods for proving theorems. When it was pointed out that they had already studied that material they replied that they could not recall this and they did not ask questions because everything seemed to be clear.

During the time devoted to studies (38 lessons of 45 minutes each) an average of 600 portions of material were considered that embraced elementary concepts in geometry, theorems and a number of axioms and postulates.[1]

The rate of assimilation proved to be very slow. In particular, the average number of assignments (portions) assimilated during a lesson was 21 (counting repeated lessons). There were significant differences among individuals in the rate at which programmes were completed (ranging from 6 to 35 portions per lesson). Some students found time to study more than 1,000 portions while others barely assimilated 200.

The number of repeated lessons in the first part of the programme consisting of 200 portions was also counted.[2] Only 21 per cent of the students studied the material only once; 20 per cent studied it twice; 48 per cent studied it three times and in that third group most students continued to display inadequate knowledge after their test.[3]

The average number of errors after the first run through the programme was 13.45 per cent and for the last 4.95 per cent which corresponds to Skinner's acceptable level (5 per cent). The results of the concluding test of assimilation were very low. The action of associating an object with a concept was carried out correctly in 31 per cent of the problems. Only 20 per cent of the students carried out that action in such a way as to display evidence of reasoning and generalization. A conscious awareness of actions was displayed by 13 per cent of students. Only 10 per cent of the students gave evidence of transferring the action of associating objects with concepts to new situations. Similar results were found in testing the action of inference.

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[1] It should be pointed out that most students studied these portions more than one time. Numerical data were collected for 174 students; 16 students were excluded from the analysis for a variety of reasons.

[2] This part of the programme was selected because it was the only one that all students had time to study.

[3] The remaining 20 students (11 per cent) did not assimilate the material either but we do not. take them into consideration because they followed the programme only once or twice. For various reasons they could not continue their studies a third time.

In carrying out these actions students displayed an inability to work with essential object attributes. In the overwhelming majority of cases the sets of concept attributes were incomplete. For example, in explaining his definition of supplementary angles a student wrote: "It is not necessary that they have a common vertex but they must have a common side." Having selected an initial set of attributes students frequently altered it in the course of their work: they lost some attributes and added others. They did not understand that in order to associate an object with a concept it is necessary to verify the presence of the entire system of necessary and sufficient attributes of the corresponding concept: frequently objects were associated with a concept when they possessed only one attribute from the entire required system. In addition the content of concept attributes was often incorrectly understood. For example, the equality of angles could mean their symmetric position, the equality of their sides as drawn on a diagram, and even the equality of the small arcs with the help of which angles were denoted on diagrams.

Only three students (2 per cent) were able to prove a theorem on vertical angles. These results did not improve even when the theorem was presented a second time, together with a diagram with headings "given" and "to be proved" as well as with a prompting instruction. In the course of arriving at a proof students confused what was given to them with what they were asked to prove. Some of them sought unsuccessfully to reproduce the steps in the proof indicated in the programme, while others "proved" the theorem by measuring angles on the diagram with a protractor.

An ability to apply axioms was found in 58 per cent of the cases. But only 20 per cent of the students were able to correctly explain their actions.

The students' retention of visual material was also low. Assignments on the recognition of geometric objects were carried out correctly in 60 per cent of the cases and reproduced correctly in 50 per cent of the cases.

When problems were stated in verbal form a recognition of attributes of corresponding geometric objects took place in 64 per cent of the cases and a reproduction of the required attributes in 25 per cent of the cases.

Similarly the results of other check tests were unsatisfactory. In particular, the symbols of geometry remained unassimilated. Most students did not designate angles correctly and did not read the names of these angles correctly. They did not always distinguish clearly the fundamental difference between indicated objects and the corresponding symbols (29; 31).[1]

Thus this programme cannot be viewed as a suitable basis for acquiring knowledge in plane geometry. Yet it was constructed in accordance with all the principles specified by Skinner, and in organizing the experiment all specifications indicated by its designers were followed. In our experiment it led to neither a development of thinking nor an acquisition of knowledge of this subject matter. This is explained by the fact that even though students worked actively with the programme at the lessons this activity did not correspond to the objective of teaching plane geometry. The activities of students related to searching for words that had to be entered into the programme. This did not always require even an understanding of the reason why a given answer is correct, and as a result students frequently answered without being aware of the essential relations of objects and were guided only by verbal relations within the context of one or two frames. As a result the overwhelming majority of students at best memorized individual expressions but were not able to apply them correctly.

An excessive subdivision of materials and frequent repetitions, which were intended to facilitate assimilation, in fact produced the opposite effect. Students lost the thread of the argument and further repetitions created a false impression that they already understood the material, thus reducing their attention. Nor is it surprising that their interest in studies was low: after receiving a confirmation of the correctness of their answers students were not generally satisfied since they did not feel they had mastered the material. As a result that reinforcement "did not work".

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[1] For purposes of comparison all the tests were given to sixth-grade students following a traditional approach to studies. For all problems they displayed higher indicators than those who were taught through Curtis' linear programme.

Accordingly that programme does not provide for developing the cognitive activity among students that is necessary in order to reflect essential, logical, and geometric relations that constitute the subject matter of this particular discipline. As a result this subject was not assimilated.

Of course it is possible to cause students to remember the content of a subject, but in the case of mathematics this will not represent its assimilation. Accordingly the programming principles by Skinner should be applied only in those cases in which assimilation at the level of memorization alone is sufficient without an emphasis on meaning. In the case of human learning such cases are rather the exception than the rule. This means that forms of programmed instruction that neither program nor guarantee the development of rational types of cognitive activities, including specific types of thinking (mathematical, linguistic, historical, etc.), cannot be effective and will not lead to substantial improvements in the practice of instruction.

§ 7. The Behaviourist Theory of Learning in the Light of Methodological and Cybernetic Requirements

The biologistic approach employed by advocates of the behaviourist theory of learning enters into a direct contradiction with the Marxist understanding of the human psyche and of human activity as a whole, whose development and functioning is viewed as subordinate to social laws.

The behaviourist theory's neglect of the specifically human properties is reflected in its identification of the object of regulation. While they correctly emphasize the role of student actions in instruction advocates of the behaviourist approach to the process of learning also limit the application of this principle to external responses alone. It is the sum of external responses rather than cognitive actions that constitute the content of instruction objectives. As a consequence the corresponding regulation programmes are directed at reinforcing the executive parts of actions which operate as the object of regulation, while the cognitive activities, which should be the objects of regulation, are generally unaffected.

For, indeed, the feedback relation in such systems carries only information on the correctness of external responses. The problem of programming the qualitatively specific transition states in cognitive activity is not even formulated. At the same time the development of external responses is represented in purely quantitative terms, namely, through the principle of the attenuation of promptings: while initially prompts are extensive they are gradually decreased and eventually the responses are carried out completely autonomously. The process of the development of behaviour, too, is also represented in quantitative terms: it is divided into a number of steps. No qualitative changes are taken into consideration either during the development of behaviour itself or in relation to individual responses: from the very beginning they develop in the same form in which instruction objectives are specified, in terms of external responses and of external motion.

If one examines such a theory of programmed instruction from the point of view of the regulation principle employed in its application it will become evident that it relies on the principle of "black box". For the structure and transition states of the cognitive activities producing the specified outcome (a correct answer) remain unknown. The feedback relation does not convey any information concerning them. This is the principal limitation of all varieties of the behaviourist approach to instruction and this explains why they differ little in their actual effectiveness.

At first glance Crowder's system appears to possess a greater degree of adaptability than does Skinner's. Indeed, Skinner's programmes only permit students to work at different rates, while their content is generally identical for all students and the correcting influences on student responses are not taken into account.

In branching programmes, on the other hand, an adaptation occurs to different levels of difficulty as well as to rates of progress. A systematic process of corrections is carried out that is directed at eliminating those errors that the students make. But such corrections are effected after the errors have been made (this is, therefore, the crudest type of regulation) and without a knowledge of the specific properties of those activities of students that result in incorrect answers. Actually, the reasons for errors is seldom clear, and correcting activities are insufficiently directed. In principle a student may arrive at correct answers through a purely mechanical process of comparisons. In short, the system of main influences, these programmes' correcting operations are concerned with outcomes, i.e. external responses rather than cognitive activities. This type of regulation does not lead to an increased effectiveness in instruction hence one finds no significant differences in effectiveness in Crowder's and Skinner's programmes.

A neglect of the real object of regulation, namely, the students' cognitive activity, is thus the fundamental shortcoming of all the variants of programmed instruction that either consciously or unconsciously embody the behaviourist view of the teaching-and-learning process.

§ 8. Major Critiques of the Behaviourist Approach to Programmed Instruction

From the very beginning the ineffectiveness of applications of the behaviourist variant of programmed instruction in human teaching has been pointed out in American literature. A number of studies have noted that the simple formula of stimulus-response-reinforcement is not sufficient in relation to human behaviour, and is too coarse for analyzing the process of learning. For exampe, Goldbeck and Briggs write that such a simplified view of learning ignores the actual basic determining factor in relation to the learning process, namely, the participating students' psychic activities ("complex hidden behaviour") (236).

There are several branches of that criticism. First, there are objections to the very principle of applying to the process of human learning the findings obtained through the study of animal learning. This is viewed as having been the source of many failures in applying to school situations methods of programmed instruction that were based on behaviourist theories. In this connection, Thelen writes that instruction seeks to activate the students' higher mental processes rather than to reduce all of instruction to what may be attained through the lowest-level mental processes that are employed in rats, pigeons and monkeys. The experience of teaching should be studied rather than the training of animals (313).

Miller, Galanter and Pribram (272) express the same view, noting that rats are so much lower than human beings that it is difficult to understand why psychologists consider that general conclusions relating to the structure of cognitive processes in rats may be transferred to man.

The principles of programming proposed by Skinner have also been criticized for not providing for a development of thinking. It has been noted that the criterion of education is achievement in mental development. This includes an ability to discuss, to develop hypotheses and to solve new intellectual problems. The need to develop creative thinking and the ability to transfer the attainment of knowledge to new conditions are particularly emphasized. Existing programmes not only do not provide for these requirements, but do not even guarantee understanding (205; 252; 231).

Thus, J. W. Blyth emphasizes that the method of simple training should not be overestimated. Training that is accompanied by reward leads to correct conduct of rats in a labyrinth. But he correctly notes that their behaviour is guided by the rewards alone and not by the logic of the labyrinth. Similarly, students may also be trained to give correct answers to certain questions, but this will not yet constitute a study of the subject and an understanding of its logic (205).

The next aspect that is criticized then follows logically, namely, the use of correct answers as the criterion of effectiveness of programmed instruction. For the selection of a correct answer or its construction does not yet mean that the students have received the necessary knowledge (215).

Thelen (314) writes that in the process of instruction the teacher should be interested not only in the end product but also in the ways through which the student arrives at these results. The same view of the need to develop the students' cognitive activities is emphasized by Gagné and

Brown in their analysis of the mechanism through which achieved knowledge is transferred to new conditions. They point out that the source of a positive transfer of knowledge lies not in behaviour itself (in the correct response), but in the nature of mediating behaviour and in the thinking activity of students (231).

It has already been noted that Skinner considers that thinking is formed by the same operant scheme as other acts of behaviour. In defining the ideas and principles of programmed instruction, however, he did not view the development of student cognitive possibilities as one of the objectives. In his programme article, "The Science of Learning and the Art of Teaching" (301) he states explicitly that he does not include the development of students' mathematical thinking among his objectives; his task is to teach them the basic rules of the given subject in the shortest possible period of time.

A natural question then arises: precisely what does Skinner have in mind? He himself does not provide an answer. If one understands the basic rules of subjects only as memorizing and an ability to respond correctly under strictly determined conditions then programmed instruction should only be applied to those rare cases in which a formation of strict habits is needed.

Yet, this does not appear to be the case, since both Skinner himself and his followers apply the principles that he advocates to the programming of practically any discipline. But then a comprehensive assimilation of the subject is not possible without a development of the corresponding thinking acts and abilities. It is fundamentally incorrect to separate knowledge assimilation from the development of thinking. The teaching-learning process requires that both these problems be solved simultaneously (or else neither one of them is solved). In particular, not a single mathematical subject can be genuinely assimilated without mathematical thinking. This is not only an objective for the participating students but a necessary means. Mathematical knowledge proper always underlies individual components of specifically mathematical acts of thinking. But since these acts themselves may be developed only in specifically mathematical contexts, the process of assimilating mathematical subjects and the process of developing mathematical thinking cannot be separated from each other (56;

57; 168). This is also confirmed by Skinner's own programmes. In particular, an experiment carried out by Gabai has shown that programmes that do not provide for the development of mathematical thinking procedures do not even teach students the "basic rules of the given subject".

In the teaching-learning process the concern for knowledge is always a concern for the particular activity that knowledge will serve, for knowledge does not exist in isolated form. If these activities are concerned with memory then knowledge will not be assimilated in terms of its specific content and its effectiveness will be quite low. If, on the other hand, knowledge constitutes an element of thinking activity that corresponds to the specific features of the subject being studied it will acquire an altogether different potential.

The behaviourist approach to programming cannot lead to a comprehensive assimilation of knowledge, since it does not control the assimilation of rational thinking procedures and of cognitive activity generally.

We have been primarily concerned with analyzing Skinner's system. This is because it is the only system of programmed instruction embodying the behaviourist approach to learning in a consistent manner. As a result it forms the most appropriate model for establishing the inherent capacities of the behaviourist theory of learning in developing programmed instruction. The ineffectiveness of the behaviourist control of the process of learning is increasingly recognized by specialists in programmed instruction. In particular, A. Roe mentions that the mental efforts that have been applied to the development of the behaviourist approach have in fact been colossal in relation to the usefulness of the corresponding results. And he voices a concern that this may also occur in the case of programmed instruction (289). Similarly following an analysis of Skinner's and Crowder's systems Thelen has concluded that the validity of this type of programme is both unclear and theoretically questionable (313).

At the present time the efforts of many researchers in other countries, including the United States, are concerned with a search for ways to control the cognitive activities of students. Problems on the mental development of students in the process of programmed instruction were already emphasized in 1968 at the UNESCO seminar on problems of programmed instruction held in Varna.[1] In the report of G. O. M. Leith, which was the principal one on these problems, it was noted that in the initial stages of programmed instruction an emphasis was placed on instruction objectives, the analysis of particular subjects being studied, and feedback. Programming methodology emphasized the subject's content and its logic. He added, however, that an analysis of the subject does not indicate what students must do in order to arrive at specified objectives, i.e., what type of activities they are required to carry out.

It is in a neglect of students' activities that Leith sees the principal shortcoming of the first stage in the development of programmed instruction. The seminar's participants unanimously agreed that the major task of the theory of programmed instruction is a search for ways to control the students' cognitive activities. We have seen, however, that this cannot be done through the behaviourist approach. In order to solve that problem it is necessary to turn to other psychological theories that satisfy the requirements of effective control of human cognitive activities. A UNESCO symposium held at Tbilisi, 1976, was concerned with the psychological bases of programmed learning. It showed that an increasing rejection of behaviourist principles was taking place because they had not been effective with regard to problems of programmed instruction. The efforts of specialists from many countries, including the homeland of behaviourists, are now concerned with the study of processes lying between stimuli and responses and with developing cognitive abilities and abilities to learn (235).

An intense development of cognitive psychology (250; 208; 224; *et al.*) indicates that a disenchantment with behaviourism has occurred in other fields of psychology as well.

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[1] The work of this seminar has been described in our brochure (169).

CONCLUSION

The idea of programmed instruction arose independently of the theory of control (cybernetics). However, a consistent implementation of that idea which calls for increasing the effectiveness of the teaching-learning process through control, requires that one turn to cybernetics, which studies the general principles governing the control of any process. The essence of programmed instruction lies in designing the teaching-learning process in accordance with the requirements of a general theory of control.

A view of programmed instruction as an application of the theory of control to the teaching-learning process presupposes an elaboration of those psychological and pedagogical foundations of control that make it possible to take the specific features of the given process into account. Only a synthesis of the general theory of control with a psychological theory of learning that is appropriate from the point of view of control theory requirements provides a basis for programmed instruction. Yet, an analysis of existing studies in programmed instruction shows that, in fact, instead of combining these two principles—the cybernetic and the psychological-pedagogical ones—either only one of them is taken into account or, more frequently, neither is applied in a consistent way.

A neglect of the specific principles that govern learning leads either to empiricism or to a mechanical transfer to the teaching-learning process of principles governing tho control of technical systems. A failure to understand the importance of a general theory of control will inevitably lead to an insufficient appreciation of conditions needed for effective control.

In examining learning as a type of control, one should first identify the process that is to be controlled and clarify its specific characteristics. In the present case this refers to the learning process. Knowledge is always the outcome of particular cognitive actions, and a control of the process of assimilation of knowledge may only be achieved through a control of cognitive actions of those who are taught. The following is a specific feature of the relationship between knowledge and activities: on the one hand, the quality of knowledge is influenced decisively by the nature of the cognitive activities, and on the other, in most cases the required cognitive activities must themselves develop and be perfected in the course of the assimilation of knowledge. In the present case, accordingly, it is the need to control cognitive activities that constitutes the specific feature of the control of learning. This is also the source of difficulty in applying a general theory of control to the teaching-learning process.

In selecting a form of control, it is necessary to consider that the function of teaching is to develop a rational structure for man's cognitive activities. It follows that it is ineffective to control the teaching-learning process in accordance with the outcome of assimilation since the relationship between assimilation and the preceding cognitive activities is non-unique.

In view of the complexity of the teaching-learning process, as well as its dependence on a number of factors, it also follows that a cyclic form of control is needed, based on feedback and a correcting system.

Cyclic control is carried out in accordance with the following procedure: a) the objective of control is specified; b) the initial level of the process under control is established; c) a programme of operations is determined providing for the basic transitional states characterizing the process; d) provisions are made to convey information in accordance with a specific system of parameters describing the state of the controlled process at each moment of control (feedback) and e) the information that is received through the feedback channel is processed and corrective operations are elaborated and carried out.

In order to apply these requirements to the process of knowledge assimilation it is necessary: a) to identify the basic elements of cognitive activity; b) to indicate the system of independent characteristics that make it possible to describe both these elements and the overall cognitive activity; c) to identify the basic qualitative stages through which each of these characteristics and the overall cognitive activity pass as they develop. It is not possible to programme the teaching-learning process or to control its course without such knowledge. Because of this, a theory of learning that does not have access to such data will not be able to provide an effective psychological basis for programmed instruction.

An analysis of those learning theories that are in some measure related to programmed instruction indicates that only the theory of stage-by-stage development of mental actions provides a psychological model of the assimilation process and makes it possible to analyze the cognitive activity itself, which is the object of control in the instruction process. At present, however, a leading role in the theory and practice of programmed instruction is played by the behaviourist theory of learning. It is the only model that is employed in programmed instruction with some degree of consistency both in the USA and in many other countries in which the American principles of programming were accepted. Differences are found only with regard to specific problems relating to the implementation of the general stimulus-response-reinforcement scheme and of the general laws of effect, exercise and readiness. This is shown not only by an analysis of existing systems of programmed instruction, but also by an analysis of research work in this area which basically proceeds along two directions: a) an elaboration of the principles proposed by B. F. Skinner, and a search for ways of implementing them and establishing their validity in the teaching process; b) a study of the contested issues that serve as a watershed in relation to other approaches.

Experimental verification of the principles of programming that follow from the behaviourist approach to learning has not confirmed the validity of these principles. The ambivalence and frequently contradictory character of the results that such attempts at verification have produced are attributable to the fact that the role of each principle was examined without control procedures in relation to the participants' cognitive activities which constitute the primary measure of instruction effectiveness.

The fundamental limitations of the behaviourist conception of teaching derive from its exclusive concern with certain external manifestations of teaching (stimulus-response) instead of a development and analysis of overall cognitive activity. There is an increasing awareness of the ineffectiveness of such a control of human learning. Today the central task of the theory of programmed instruction is the search for ways to control the cognitive activity of students. But these cannot be found unless one abandons the behaviourist position.

The theory of stage-by-stage formation of mental actions represents a natural step in the development of Soviet psychological science. It is based on the fundamental principles of Soviet psychology that were formulated at the end of the 1940s in the works of Vygotsky, Leontiev, and Rubinstein and of their disciples: 1) an activities-oriented approach to the subject of psychology; 2) a recognition of its integral unity with external practical activities; 3) an understanding of the social nature of human psychic activities.

On the basis of these principles and of experimental data accumulated by Soviet psychologists, in the early 1950s Galperin proposed a theory of stage-by-stage formation of mental actions. This in turn has served as a basis for the subsequent development of the principles of Soviet psychology and, above all, this refers to the principle of an integral unity of psychic and practical, internal and external activities.

Because of its social nature man's psychic activity is transmitted from generation to generation not through biological heredity but through teaching activities and the assimilation by new generations of socially generated products, means and types of activity. While they are initially assimilated in their external forms, they are then transformed into an internal psychic form. This is the essence of the theory under consideration.

Such transformations proceed through a system of independent characteristics (parameters) and it is combinations of corresponding qualitative changes that constitute the progressive stages through which external material activities pass in acquiring the forms of psychic activities. In the course of this process the external objects to which activities relate are replaced by corresponding images, representations, and concepts, while the practical operations are transformed into mental and theoretical operations.

The process through which new psychic phenomena are formed thus acquires a distinctive system of characteristics that reflect basic changes in psychic activity and also determine its other qualities and properties. It is in relation to this process that the basic transitional stages were first identified that reflect the progressive development of acts of psychic activity. Galperin's theory thus opened the way to concrete psychological studies of psychic activity itself, and also provided a means for the development of pre-specified forms and types of psychic activity.

The present conception differs fundamentally from that of behaviourist theory in that it is directed towards an analysis of the assimilation process and the cognitive activities of the students rather than to a simple recording of the outcomes of this activity dependent on a teacher's actions.

The identification of actions as the basic unit of analysis of cognitive activities and as the central link in controlling its development permits this theory to reveal the structure of a corresponding action and of its operating components. It provides a system of independent characteristics of cognitive activity that are needed both for programming various types of cognitive activities and for controlling their development. It also provides a basis for programming the basic states (the basic stages of assimilation) of cognitive activities.

The studies conducted by Galperin and carried out under his direction have made it possible to identify in all actions their orienting and executive parts, while with the former, they have made it possible to identify proper-orienting and controlling parts. As a result any human action may now be viewed as a specific form of control micro-system which includes a "control component" (the orienting part of action), a "working component" (the executive part of action) and a "monitoring and comparing mechanism" (the controlling part of action).

It has also been established that the orienting bases of specific actions may be constructed in different ways, and experimental studies have identified the more effective types of the orienting basis of action.

The development of a systems-oriented (third) type of the orienting basis of action makes it possible to form generalized procedures for cognitive activity, that provide for autonomy in the person's subsequent orientation in all specific instances of particular types of objects within the given area of knowledge.

In view of the constructive nature of this theory as well as of its effectiveness in experimental applications, it is our view that it provides the psychological basis that is required for programmed instruction. It leads to a new approach to programming that makes it possible to envisage the programming of rational types of cognitive activities and to specify the development of such essential characteristics of cognitive activity as its form, degree of generalization, rationality and conscious awareness.

A reliance on the principles of control that emerge from that theory makes it possible to produce, during the formation of the initial scientific concepts, a course of the knowledge-assimilation process that differs fundamentally from the one that occurs in usual teaching practice. From the very first students orient themselves on a system of essential attributes, i.e., act rationally. Errors are few in number and are easily corrected by the students themselves. The students not only act correctly, but justify their actions correctly as well, since they are consciously aware of their knowledge and abilities. They also display confidence in their knowledge and actions. An adherence to a number of conditions that were identified experimentally produces a high degree of generalization in the knowledge that is developed. This is independent of the object's perceptual attributes. Finally, a control of the assimilation process makes it possible to form comprehensively developed mental actions in preschool children, including all the attributes mentioned above.

Aside from providing an alternative approach to the assimilation of concepts the control of student activities represents a new approach to the study of that process. More specifically this includes: a) approaching knowledge development in terms of the activities that lead to them; b) following its assimilation under conditions when this activity proceeds in an organized rather than an unorganized manner. This is of considerable importance because it is only under conditions of effective control that the laws governing the process of assimilation may be studied as a specifically human way of acquiring experience. A realization of the principles of control that emerge from the theory of stage-by-stage formation of mental actions makes it possible to control not only the assimilation of individual mental actions but the procedures of cognitive activity and to develop them with pre-established qualities.

There are grounds for believing that a systematic approach to instruction that follows these control principles will enhance development as well as assimilation. Instruction operates as a source of development and creates new zones of potential development. Accordingly, changes in types of instruction lead to changes in types of development. This hypothesis is now supported by experimental data as well as theoretical considerations. A number of Soviet psychologists (P. Ya. Galperin, N. G. Salmina, V. P. Sokhina, V. V. Davydov, D. B. Elkonin, L. I. Aidarova, A. K. Markova, V. V. Repkin and others) have carried out a series of novel experiments and have introduced a series of fundamental changes over several years in teaching children (see, for example: 192; 150; 97; 122; and others).

Particular interest attaches to prolonged research conducted under the direction of V. V. Davydov and D. B. Elkonin in which students in experimental schools have shown not only a high level of assimilation (in mathematics, language) but also substantial advances in their level of thinking and in their "capacity to study".

At the present time these results make it possible to formulate a number of requirements that permit junior-grade students to assimilate scientific concepts and to apply methods of conscious theoretical thinking rather than merely rely on concepts in a formal manner in solving various cognitive problems. These studies suggest that junior-grade students can in fact acquire far higher level of intellectual development than that currently accepted for a given age group. They have shown convincingly that study leads to development and to the formation of further zones of potential development. The very possibility of conducting such experiments is suggestive: an activities-oriented approach to the learning process and an understanding of the social nature of the relevant principles have simplified considerably the transition from laboratory experiments to school practice. That approach has therefore brought psychologists closer to the actual principles that govern human learning.

The present theory thus offers a new and fundamentally different approach to programmed instruction. This approach produces a substantial enhancement in effectiveness of the teaching-learning process and contributes to meeting the tasks that have been set up for the Soviet system of education by the Communist Party and Government (see resolutions on problems of education in the collection: *Voprosy ideologicheskoi raboty KPSS*. Sbornik dokumentov 1965-1973 [Questions Relating to the Ideological Work of the CPSU. A Collection of Documents, 1965-1973], Moscow, 1973).

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